Spatial Working Memory in Young Adolescents with Different Childhood Trajectories of Internalising, Conduct and Hyperactivity/inattention Problems

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Abstract:

Background: In children internalising and externalising problems impact on learning. However, there is limited research on the specific impact of such problems on spatial working memory (SWM), strongly related to cognitive ability and children's learning. **Aims**: We explored distinct trajectories of internalising problems and externalising problems (conduct problems and hyperactivity/inattention) in a large general-population sample of children followed from age 3 to age 11 years. We then assessed their role in SWM performance at age 11 years. **Sample**: Data were drawn from the UK's Millennium Cohort Study. Our analytic sample was children with data on SWM at age 11 years (N = 12,589). **Methods**: There were two stages of data analysis. Trajectory group membership was firstly estimated by group-based trajectory modelling for internalising problems, conduct problems and hyperactivity/inattention at ages 3-11 years. Multiple regression then assessed the relationship between SWM at age 11 years and trajectory group membership after accounting for confounders. **Results**: Trajectories of internalising, conduct and hyperactivity/inattention symptoms across ages 3 to 11 years were related to SWM at age 11 years, even after controlling for confounding variables. For each of the three symptom domains, poor SWM was most consistently found in children with chronically high levels of symptoms. **Conclusions**: In general, atypical patterns of internalising problems, conduct problems and hyperactivity/inattention in childhood were related to poorer SWM in early adolescence.

Keywords:

child psychopathology, internalising problems, conduct problems, hyperactivity/inattention, spatial working memory, group-based trajectory modelling

Data availability statement:

The MCS data that support the findings of this study are openly available in the UK Data Service

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Introduction

Spatial Working Memory (SWM) reflects the cognitive ability to manipulate spatial-visual information (Logie, 2009). SWM, also recognised as visual-spatial working memory in the model of working memory, plays an essential role in short-term memory and long-term verbal memory that uses spatial mnemonics (Baddeley & Lieberman, 1980), and has been described as one of the two slave systems of the central executive functioning system in the model of working memory (Baddeley, 2017). Reduced SWM capacity is associated with difficulties in cognitive activities including mathematics learning (Aronen, Vuontela, Steenari, Salmi, & Carlson, 2005; Soltanlou et al., 2019). Thus, understanding what may explain poor SWM in children in the first place is important for both prevention and intervention.

Child psychopathology, commonly categorised into internalising problems (indexing depressive and anxiety symptoms) and externalising problems (indexing hyperactivity and antisocial or 'acting-out' behaviours), has been associated with poor cognitive outcomes in general (Blanken et al., 2017; Flouri et al., 2018), but the research into its specific role in SWM is limited and showing mixed findings (Saarinen et al., 2015). For example, Blanken et al. (2017) found in their sample of 1177 children that the visuospatial processing of those with internalising and/or externalising problems appeared significantly different from that of their typically developing peers but this difference became nonsignificant when confounding was accounted for. By contrast, Martin, Davies, Cummings, and Cicchetti (2017), who followed children in 235 families from age 6 to age 14, showed that childhood emotional insecurity and attention problems predicted worse SWM in adolescence, even after adjustment.

The evidence for a link in clinical groups or in adults is more consistent. For example, anxiety and depression seem to impact on SWM and their impact seems to vary by their severity. Christopher and MacDonald (2005), for instance, reported impairments in all components of working memory of 35 patients with clinical depression. In another study, anxiety caused by threat of shocks seemed to affect SWM in young adults, and higher levels of anxiety were related to worse SWM (Shackman et al., 2006). However, anxiety and stress did not show significant effects on SWM in Lukasik et al.'s (2019) non-clinical sample of 503 adults. Externalising disorders [Attention-Deficit/Hyperactivity Disorder (ADHD), Conduct Disorder (CD) and Oppositional Defiant Disorder (ODD) (Nivard et al., 2017)] seem to be more strongly linked to deficits in SWM, but there is significant specificity by type, with ADHD being more consistently and more strongly associated with impaired working memory in general. For example, three meta-analyses (Schoemaker, Mulder, Deković & Matthys, 2013; Martinussen et al., 2005; Willcutt et al., 2005) reported small to large effect sizes of impaired working memory in children with ADHD, with researchers emphasising the importance of working memory deficits in the visuo-spatial domain in particular (e.g., Ferrin & Vance, 2012; Lui & Tannock, 2007), although null associations have also been found (Brocki, Nyberg, Thorell, & Bohlin, 2007). Associations with ODD and CD are less consistent. Oosterlaan et al. (2005) examined performance on working memory, verbal fluency, and planning tasks in children 6 to 12 years old and reported that deficits were present in children with ADHD and those with comorbid ADHD and ODD/CD, but not in children with only ODD/CD. Likewise, Thorell and Wåhlstedt (2006) found that inhibition, working memory, and verbal fluency in preschoolers were related to ADHD, but not ODD, in both categorical and dimensional analyses. However, Saarinen et al. (2015) showed that their sample of 26 children with ODD/CD aged 7 to 12 had significantly worse SWM compared to the control group, even after controlling for ADHD

comorbidity. More recently, Griffith et al. (2017) found that difficulties in working memory and sustained attention were related to negative affect symptoms of ODD, but not to oppositional and antagonistic behaviour.

The present study

In summary, it appears that there is an association between deficits in SWM and several domains of child psychopathology which seems to vary in strength by domain. However, most of the research to date is cross-sectional and with small, selective samples. It is therefore unclear what the association is in the general child population, especially when a longitudinal lens is applied, which is important given the temporal instability of child psychopathology symptoms in the general population. This study attempted to fill this gap using longitudinal data from the Millennium Cohort Study (MCS), a large general-population sample in the UK. In view of the increasing evidence that in the general child population the trajectories of such symptoms (broadly defined as internalising and externalising) can be divided into different types with distinct characteristics (Fanti, 2010; Flouri et al., 2018; Korhonen et al., 2018; Nivard et al., 2017), we examined in this study the role of different trajectory groups of internalising symptoms and externalising symptoms (hyperactivity/inattention and conduct problems in the present study) in later SWM performance. Given that the association between SWM and externalising symptoms differs by symptom domain, we modelled the SWM links with hyperactivity/inattention and conduct problems separately.

Methodology

Participants

Our data came from the Millennium Cohort Study (MCS), a sample of 18,818 children (in 18,552 families) who were born between 1 September 2000 and 31 August 2001 in England and Wales, and between 24 November 2000 and 11 January 2002 in Scotland and Northern

Ireland (Connelly & Platt, 2014). There are seven survey sweeps to date conducted when children were at an average age of 9 months, and 3, 5, 7, 11, 14, and 17 years (*CLS | Millennium Cohort Study*, n.d.). The recruited sample was clustered at electoral ward level and was disproportionately stratified to overrepresent poor areas, areas with more ethnic minorities in England, and areas in Wales, Scotland and Northern Ireland (Hansen et al., 2014). Ethics approval for the MCS was obtained from NHS Multicentre Research Ethics Committees. Consent was received from parents and assent from the children themselves from age 11 years. In MCS, SWM was measured at Sweep 5, and symptoms of child psychopathology were collected via an interview with the main carer since Sweep 2. Therefore, we used data from Sweeps 2 to 5 for this study. Our analytic sample was children (singletons and first-born multiples) with data on SWM at age 11 years (N = 12,589). For the modelling of the distinct trajectories of internalising, conduct and hyperactivity/inattention symptoms across Sweeps 2-5 we included all MCS children with data on symptoms on at least two sweeps. Figures 1 and 2 show the flow charts for all analyses.

[insert Figure 1 and Figure 2]

Measures

Spatial working memory

SWM was measured at age 11 with the SWM task of the Cambridge Neuropsychological Test Automated Battery (CANTAB) (Robbins et al., 1994). Participants are shown on a computer screen several coloured boxes, some of which contain blue tokens. They need to find the tokens by touching the boxes and move the tokens to a column on the screen (Figure 3). The difficulty level increases as the number of boxes increases from 3 to 8. Once a token is found in a box and placed to the column, another search starts, and the token could be in any of the other boxes. A trial is completed when all the tokens from the simultaneously presented boxes are found. Responses are recorded as errors when participants touch boxes which had already been found

empty within one search (within errors) or revisit boxes which previously contained tokens within one trial (between errors). The colour and position of the boxes changes from trial to trial to avoid the use of stereotyped search strategies. In MCS, participants had a chance to practise 3 trials with 3 boxes in each trial prior to the test. The test consisted of 3 blocks with 4 trials in each; the number of boxes increased from 4 to 6 to 8. Participants' performance was measured by *total errors* and *strategy* (Atkinson, 2015). 'Total errors' was the sum of within and between errors that participants made across trials. 'Strategy' measured participants' use of an efficient search method of returning to the same box at the beginning of each search. Strategy was recorded as the frequency of touching a box at the beginning of a search which was different from the one touched at the beginning of the previous search. Higher scores on total errors and lower scores on strategy suggested poorer SWM performance.

[insert Figure 3]

Internalising, conduct and hyperactivity/inattention problems

These were all measured using the parent-reported Strengths and Difficulties Questionnaire (SDQ) (Goodman, 1997) scores at Sweeps 2-5 (MCS 2-5). SDQ measures symptoms in four areas, namely, emotional symptoms, peer problems (both of which index internalising symptoms in the general child population, as explained), conduct problems and hyperactivity/inattention. In line with established practice (https://www.sdqinfo.org/a0.html), we considered emotional symptoms and peer problems as two types of difficulties within the one domain of internalising problems. Given that hyperactivity/inattention symptoms tend to be more consistently related to SWM than conduct problems, these two types of difficulties were analysed separately. We banded children's scores in all areas to two levels (0 = normal; 1 = at risk) according to established cut-offs (Goodman, 1997) whereby children with scores below cut-off are considered 'normal' (80% in the general population), and those with scores above cut-off are considered 'at risk'. For internalising problems, 0 referred to scoring below

cut-off on both emotional symptoms and peer relationships and 1 to being at risk of either emotional or peer problems.

Confounding variables

Confounding variables, that correlate with both SWM and internalising, conduct and hyperactivity/inattention problems in children, were included as covariates in the regression analyses to rule out alternative mechanisms that explain the outcome of interest (Frank, 2000). These included *exact age*, *verbal ability, gender*, *maternal depression*, and *socio-economic status (SES)* (Blasiman and Was, 2018; Voyer, Voyer, & Saint-Aubin, 2017; Hughes et al., 2013; Dekker et al., 2007; Leve et al., 2005; Mesman et al., 2001; Cummings & Davies, 1994). *Age* was children's age in months at MCS5. *Verbal ability* was measured at MCS5 with Verbal Similarities, a British Ability Scales (BAS) subscale for verbal knowledge and verbal reasoning ability (Elliott et al., 1996). *Maternal depression* was measured using the 'Kessler 6' from MCS2 to MCS5 (Kessler et al., 2003) and was given as mean number of sweeps that the mother reported as having clinically meaningful depression (above cut-off, i.e., score of 6). We approximated *SES* by family poverty, maternal education and ethnicity. Family poverty was measured by the Organisation for Economic Co-operation and Development (OECD) indicator that the family was above or below the poverty line for MCS2 to MCS5. We generated a variable for the mean number of sweeps that the family was below the poverty line. Maternal education was measured by a dummy variable indicating whether the mother had a university degree or not. Ethnicity was a categorical variable of belonging to one of the 6 UK Census ethnic groups at MCS5.

Analytic strategy

Two sequential stages of data analysis were conducted in STATA. Firstly, Group-Based Trajectory Modelling (GBTM), a statistical method which allows subgroups of similar trajectories of one outcome to emerge from the data (Nagin, 2005), was used to estimate

different trajectory groups for internalising, hyperactivity and conduct problems in childhood (ages 3-11 years). GBTM simultaneously estimates (a) the probabilities of individuals being assigned to each group by a multinomial logit model and (b) the longitudinal trajectories by polynomial functions of age (e.g., zero order as constant, first order as linear, second order as quadratic) (Hickson et al., 2020; Nagin, 2005). GBTM in our study is fitted up to a quadratic relationship because the data available were collected at 4 time-points and at least 5 are needed to fit a higher order model (King et al., 2018). For GBTM, we used *Traj*, a free plugin in STATA. GBTM parameters were estimated by Full Information Maximum Likelihood (Nagin, 2005). Each GBTM included age, the outcome (binary, as explained) and the sampling design weight. Several criteria were used to find the best-fitted model (Nylund-Gibson & Choi, 2018), including the Bayesian Information Criterion (BIC), the Average Posterior Probability of Assignment (AvePP) and the Odds of Correct Classification (OCC). The second stage of data analysis explored differences in SWM by trajectory group membership, using multiple linear regression modelling. All multiple regression models, fitted using the command *regress*, reflected the stratification and clustering of the MCS study design by using the *svy* command (Ketende & Jones, 2011). Missing data were handled with multiple imputation by chained equations (MICE) using the *mi* command (Jakobsen et al., 2017; Royston, 2004).

Results

GBTM

Table 1.1 presents the tetrachoric correlations and descriptive statistics for internalising, conduct and hyperactivity/inattention problems at Sweeps 2-5. Internalising, conduct and hyperactivity/inattention problems were positively correlated (all p < 0.01), as expected. The proportion of children at risk of internalising problems ranged from 22.79% to 29.70% across the four sweeps. In total, 51.24% children were at risk of conduct problems at MCS2, 22.57%

were at risk at MCS3, 20.56% at MCS4 and 20.15% at MCS5. For hyperactivity/inattention these proportions were, respectively, 24.79%, 17.95%, 19.76% and 17.09%.

[insert table 1.1]

Internalising problems

For the GBTM of internalising problems, data on 14,226 children (total N of observations = 50,778) were used. The model fit indices of the 2 to 6 group solutions are shown in Table S1.1 of the Supplementary Material. BIC values indicated that the 4-group model was better than the other models. Children with low levels of internalising problems tended to show a stable trajectory which can be modelled as a constant polynomial function of age. Therefore, models with one group modelled as a constant function of age were tested alongside models including linear or quadratic functions of age. Table S2.1 summarizes the fit indices of these 32 4-group models. The model selected was the one with the largest BIC value and where the highest-order coefficients for each group were all significant. Figure 4 describes the four trajectory groups: 'no risk' (30.9% of the sample), 'deteriorating' (10%), 'low risk' (41.2%) and 'high risk' (18%). The 'no risk' group seemed to never show internalising symptoms across the study period. In the 'deteriorating' group, the proportion of high scorers of internalising symptoms increased sharply from age 5 (approximately 0%) to age 7 (approximately 40%), further increasing to 60% by age 11. For the 'low risk' group, the proportion was approximately between 10% and 40%. The 'high risk' group exhibited a relatively high proportion of high scorers (> 60%) consistently during childhood.

[insert figure 4]

Conduct problems

For the GBTM of conduct problems, data on 14,242 children (total N of observations = 50,918) were used. Again, the 4-group solution showed a better fit than solutions with 2, 3, 5 or 6 groups (Table S1.2). A total of 38 4-group models were subsequently assessed, including 16

models where each group was modelled as either linear or quadratic function of age, and 22 models with up to two groups modelled as a constant function of age, as some studies (e.g., Fanti, 2010; Korhonen et al., 2018; Gutman et al., 2019) have suggested the presence of distinct groups with consistently high and consistently low symptoms. Results are shown in Table S2.2. Figure 5 depicts the four trajectories according to the best group solution. The 'deteriorating' group (5.6%) showed an increase in proportion of high scorers from 0% at age 3 to around 30% at age 11. For children in the 'early childhood-limited' group (51.1%) the proportion decreased from about 30% at age 3 to about 0% at age 5 and remained low thereafter. The 'improving' group (31.5%) reported a high proportion at age 3 (approximately 70%) which dropped to approximately 25% at age 11. Finally, 11.8% of the sample was assigned to the 'high risk' group. In that group, the proportion of high scorers was over 70%.

[insert figure 5]

Hyperactivity/inattention

For the GBTM of hyperactivity/inattention, data on 14,249 children (total N of observations = 50,920) were used. Again, the 4-group model showed the largest BIC value which was higher than that of other models by at least 9, suggesting a strong evidence for model improvement (Table S1.3). Thirty-eight 4-group models with different combinations of polynomial function of age across 4 groups were tested, and their fit indices are presented in Table S2.3. Figure 6 describes the four trajectories according to the best group solution. The proportion of high scorers of hyperactivity/inattention problems increased from 0% at age 3 to 40% at age 11 in the 'deteriorating' group (11.8%). The average proportion in the 'improving' group (19.4%) dropped from approximately 60% to 30%. The 'typically developing' children (62.7%) showed a low proportion of around 10% at age 3, which dropped to 0% at age 5 and remained stable thereafter until age 11. Finally, the 'high risk' group (6%) had a very high proportion which increased from about 80% at age 3 to 100% at age 11.

[insert figure 6]

Sample characteristics (unweighted data)

Table 1.2 indicates that the two measures for SWM were moderately correlated (r = 0.65, p < .05), as expected. Tables 2.1, 2.2 and 2.3 present our analytic sample's characteristics by trajectory group. As expected, the children in 'high risk' groups showed more SWM errors and less consistent strategy compared to other children. Groups with the lowest average prevalence of problem behaviours (i.e., the 'no risk' group for internalising problems, the 'early childhood-limited' group for conduct problems and the 'typically developing' group for hyperactivity/inattention) showed the best SWM and highest verbal ability on average. The children in these groups also tended to come from more advantaged families (they were less likely to live in poverty, or with depressed or lower educated mothers). Missingness was in general low: 10% for group membership of internalising problems, 11% for that of conduct problems, and 10% for that of hyperactivity/inattention. Missingness on the covariates was less: 4% for maternal education, 0.02% for ethnicity, and 2% for maternal depression. Missing values were dealt with by MICE because missingness in the predictors of interest was, as shown, above 5% but below 40% (Jakobsen et al., 2017).

[insert tables 1.2, 2.1, 2.2, and 2.3]

Multiple regression models

For each SWM domain (errors and strategy) and for each symptom domain (internalising, conduct and hyperactivity/inattention) four models were fitted. The baseline model (Model 1) only included trajectory group membership. Model 2 added child gender and age at MCS5. Poverty, ethnicity, maternal education and maternal depression were further included in Model 3. Model 4, which added verbal ability, was the fully adjusted model. In all models, trajectory group membership, a categorical variable, was included as one of the explanatory variables;

the group with the average lowest prevalence of problem behaviours was taken as reference, hence no coefficients are reported for that group.

Internalising problems and SWM

The results in Table 3, which show differences in SWM by internalising trajectory group, suggest that children from the 'high risk' group, the 'low risk' group and the 'deteriorating' group made significantly more search errors in the SWM task than children from the 'no risk' group (b=3.09, SE = 0.60, p < 0.001; b=1.33, SE = 0.50, p < 0.01, and b=2.60, SE=0.92, p < 0.01, respectively), even after controlling for covariates. Girls, children with higher levels of verbal ability and children with university-educated mothers made fewer total errors, whereas poverty and being Black or Black British were associated with more total errors. Trajectory group membership had little impact on SWM strategy (Table 4): after full adjustment, children's SWM strategy performance no longer differed across internalising trajectory groups.

[insert tables 3 and 4]

Conduct problems and SWM

For conduct problems, results in Table 5 indicate that the 'improving' group (b = 1.38, SE = 0.52, p < 0.01) and the 'high risk' group (b = 3.25, SE = 0.66, p < 0.001) made more errors than the 'early childhood-limited' group. Compared to the 'early childhood-limited' group, the 'improving' group (b = 0.33, SE = 0.16, p < 0.05) and the 'high-risk' group (b = 0.70, SE = 0.21, p < 0.01) also showed poorer SWM strategy (Table 6).

[insert tables 5 and 6]

Hyperactivity/inattention and SWM

The impact of trajectory group membership for hyperactivity/inattention on SWM total errors and SWM strategy remained significant in the fully adjusted models. Compared to the 'typically developing' group all three other groups did worse in SWM (Tables 7-8), with the 'high risk' group performing particularly poorly.

[insert tables 7 and 8]

Discussion

Using data from a large general-population longitudinal sample, this study delineated distinct groups of children on trajectories of internalising, conduct and hyperactivity/inattention symptoms from preschool age until the end of primary school, and investigated whether these distinct subpopulations of children differ in spatial working memory (SWM), measured at the end of the study period. We found four trajectory groups for each symptom domain, consistently with previous studies (e.g., Flouri et al, 2018; Fanti, 2010; Gutman et al., 2019).

In general, and for all three symptom domains, children with a persistently high level of symptoms across ages 3 to 11 years tended to show poorer SWM at age 11 years. Studies with animals and patient groups have suggested that abnormal dopamine-related activities in the prefrontal cortex or dramatic changes of cortisol levels could lead to subsequent poor SWM performance (e.g., Mizoguchi et al., 2000; Murphy, Arnsten, Goldman-Rakic, & Roth, 1996; Zahrt, Taylor, Mathew, & Arnsten, 1997; Taverniers, Ruysseveldt, Smeets, & Grumbkow, 2010). Given that internalising and externalising problems, especially of the chronic type, are also associated with dysregulated dopamine and cortisol levels (Capaldi et al., 2012; Ruttle et al., 2011), children with atypical internalising and/or externalising symptoms may show poor SWM because prefrontal cortical dopaminergic dysfunction or HPA axis dysregulation cause both. If the relationships we identified are causal, however, then our findings suggest that poor SWM in adolescence, strongly associated with academic success, can be prevented by preventing emotional and behavioural problems in childhood and by intervening before they become chronic.

Our study has many strengths, including that it is the first, to our knowledge, to explore differences in SWM in early adolescence by the developmental course of a broad range of emotional and behavioural symptoms across childhood. Other strengths include its large sample size, its use of two related but distinct measures of SWM, its longitudinal design, and a robust adjustment for confounders in the analysis. However, it has some important limitations as well. Firstly, model fit for the GBTM analysis, although acceptable, could be further improved by including a cubic polynomial function of age, which we could not do as we only had four sweeps of data (King et al., 2018). Secondly, there is evidence that there might be comorbidity between internalising and externalising problems (e.g., Fanti, 2010; Flouri et al., 2018). We tried to control for such comorbidity by including externalising problems as a time-varying covariate in GBTM for internalising problems and vice versa. However, the amount of variance between observed and estimated trajectory means was large and it was also difficult to obtain model estimates. As a result, we conducted GBTM for all three domains without controlling for comorbidity. Thirdly, as already discussed, we cannot determine, given the study design and the data available, if the associations we found are causal, and if so in what direction, or whether they are due to common causes. This is an important issue because establishing causality will have profound effects on planning both prevention and intervention strategies for poor SWM, in turn a strong predictor of low academic performance and educational attainment.

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Table 1.1 summarizes the tetrachoric correlations (Spearman's ranks) and descriptive statistics of internalising problems, conduct problems and hyperactivity/inattention at children's ages 3, 5, 7 and 11 years.

Table 1.2 summarizes the pairwise Pearson correlations and descriptive statistics of SWM total errors and SWM strategy at children's age 11 years.

Tables 2.1/2.2/2.3 show distribution of variables by trajectory group of internalising problems, conduct problems and hyperactivity-inattention

Tables 3/5/7 Multiple regression models predicting SWM (total errors)

Tables 4/6/8 Multiple regression models predicting SWM (strategy)

Table 1.1 Tetrachoric correlations and descriptive statistics of internalising problems, conduct problems and hyperactivity/inattention (unweighted data)

		1	2	3	4	5	6	7	8	9	10	11	12
1.	Internalising problems, age 3	1.00											
2.	Internalising problems, age 5	0.50**	1.00										
3.	Internalising problems, age 7	0.44**	0.63**	1.00									
4.	Internalising problems, age 11	0.36**	0.48**	0.59**	1.00								
5.	Conduct problems, age 3	0.33**	0.27**	0.27**	0.28**	1.00							
6.	Conduct problems, age 5	0.30**	0.44**	0.39**	0.34**	0.54**	1.00						
7.	Conduct problems, age 7	0.24**	0.36**	0.48**	0.39**	0.47**	0.67**	1.00					
8.	Conduct problems, age 11	0.24 **	0.31**	0.35**	0.49**	0.43**	0.57**	0.66**	1.00				
9.	Hyperactivity/inattention, age 3	0.34**	0.32**	0.32**	0.29**	0.50**	0.40**	0.43**	0.35**	1.00			
10.	Hyperactivity/inattention, age 5	0.30**	0.41**	0.39**	0.36**	0.42**	0.59**	0.53**	0.46**	0.64**	1.00		
11.	Hyperactivity/inattention, age 7	0.27**	0.36**	0.45**	0.40**	0.37**	0.50**	0.63**	0.49**	0.56**	0.73**	1.00	
12.	Hyperactivity/inattention, age 11	0.24**	0.32**	0.42**	0.51**	0.37**	0.47**	0.53**	0.65**	0.49**	0.62**	0.74**	1.00
Normal:	N	10,443	11,523	10,166	9,049	7,297	11,574	10,843	10,269	11,245	12,261	10,955	10,666
At risk:	N	4,412	3,401	3,465	3,808	7,668	3,373	2,807	2,591	3,706	2,682	2,698	2,198
Total:	N	14,855	14,924	13,631	12,857	14,965	14,947	13,650	12,860	14,951	14,943	13,653	12,864

Note: *p<0.05 **p<0.01

Table 1.2 Pairwise Pearson correlations and descriptive statistics of SWM total errors and SWM strategy at age 11 (unweighted data)

	SWM total errors	SWM strategy
SWM total errors	1.00	
SWM strategy	0.65*	1.00
Mean (SD)	35.71 (18.76)	34.32 (5.94)
N	12,757	12,757

Note: *p<0.05

Table 2.1 Distribution of variables by trajectory group of internalising problems (unweighted data)

	Total N = 12,589	Range	1. No risk N = 5,300	2. Deteriorating N = 738	3. Low risk N = 3,411	4. High risk N = 1,880	p-value	Effect size
Continuous variables, M (SD)								*Eta-Squared*
SWM errors	35.27 (18.65)	[0,173]	32.95 (18.03)	37.71 (18.00)	35.77 (18.71)	39.96 (19.45)	< 0.001	.02
SWM strategy	34.22 (5.90)	[0,48]	33.78 (5.78)	34.76 (5.81)	34.37 (5.86)	34.95 (6.27)	< 0.001	.01
Age in months	133.44 (3.99)	[120,147.96]	133.49 (3.95)	131.99 (4.21)	133.69 (3.90)	133.41 (4.02)	< 0.001	.01
Poverty	0.27 (0.36)	[0,1]	0.18 (0.31)	0.29 (0.36)	0.31 (0.38)	0.45 (0.40)	< 0.001	.07
Maternal depression	0.21 (0.31)	[0,1]	0.12 (0.24)	0.27 (0.33)	0.24 (0.32)	0.41 (0.38)	< 0.001	.11
Verbal ability	58.89 (9.85)	[20,80]	60.46 (8.95)	58.71 (10.33)	58.31 (9.81)	55.59 (11.14)	< 0.001	.03
Categorical variables, n (%)								*Cramer's V*
Female	5,661 (50%)	\	2,710 (51%)	370 (50%)	1,700 (50%)	881 (47%)	0.017	.03
Mixed	300 (3%)	\	121 (2%)	29 (4%)	80 (2%)	70 (4%)	< 0.001	.04
Indian	266 (2%)	\	84 (2%)	13 (2%)	102 (3%)	67 (4%)	< 0.001	.05
Pakistani and Bangladeshi	671 (6%)	\	150 (3%)	20 (3%)	262 (8%)	239 (13%)	< 0.001	.16
Black or Black British	301 (3%)	\	134 (3%)	9 (1%)	107 (3%)	51 (3%)	< 0.001	.03
Other (Inc Chinese)	141 (1%)	\	40 (1%)	8 (1%)	61 (2%)	32 (2%)	< 0.001	.04
Mother has 1st degree	2,109 (19%)	\	1,276 (25%)	108 (15%)	534 (16%)	191 (11%)	< 0.001	.14

Total number includes 1,260 individuals with missing values on group membership.
p-values for between group F-tests for continuous variables and chi-square tests for categorical variables
Effect size: Eta-Squared for continuous variables and Cramer's V for categorical variables

Table 2.2 Distribution of variables by trajectory group of conduct problems (unweighted data)

	Total N = 12,589	Range	1. Deteriorating N = 353	2. Early childhood limited N = 7,249	3. Improving N = 2,300	4. High risk N = 1,348	p-value	Effect size
Continuous variables, M (SD)								*Eta-Squared*
SWM errors	35.27 (18.65)	[0,173]	36.06 (17.52)	33.55 (18.41)	37.51 (18.96)	40.51 (18.36)	< 0.001	.02
SWM strategy	34.21 (5.91)	[0,48]	34.65 (5.37)	33.86 (5.96)	34.63 (5.80)	35.29 (5.76)	< 0.001	.01
Age in months	133.44 (3.98)	[120,147.96]	132.35 (3.70)	133.52 (3.96)	133.59 (4.09)	133.09 (3.96)	< 0.001	.00
Poverty	0.27 (0.36)	[0,1]	0.27 (0.35)	0.21 (0.33)	0.37 (0.39)	0.45 (0.40)	< 0.001	.06
Maternal depression	0.21 (0.31)	[0,1]	0.21 (0.31)	0.15 (0.27)	0.29 (0.34)	0.40 (0.38)	< 0.001	.08
Verbal ability	58.88 (9.86)	[20,80]	57.35 (10.08)	60.13 (9.33)	57.31 (9.98)	55.19 (10.98)	< 0.001	.03
Categorical variables, n (%)								*Cramer's V*
Female	5,615 (50%)	\	170 (48%)	3,864 (53%)	1,071 (47%)	510 (38%)	< 0.001	.10
Mixed	298 (3%)	\	6 (2%)	176 (2%)	67 (3%)	49 (4%)	< 0.001	.03
Indian	266 (2%)	\	7 (2%)	166 (2%)	72 (3%)	21 (2%)	< 0.001	.03
Pakistani and Bangladeshi	668 (6%)	\	16 (5%)	386 (5%)	188 (8%)	78 (6%)	< 0.001	.05
Black or Black British	300 (3%)	\	10 (3%)	196 (3%)	70 (3%)	24 (2%)	< 0.001	.02
Other (Inc Chinese)	140 (1%)	\	5 (1%)	87 (1%)	29 (1%)	19 (1%)	< 0.001	.01
Mother has 1st degree	2,093 (19%)	\	59 (17%)	1,643 (23%)	278 (13%)	113 (9%)	< 0.001	.15

Total number includes 1,339 individuals with missing value on group membership.
p-values for between group F-tests for continuous variables and chi-square tests for categorical variables
Effect size: Eta-Squared for continuous variables and Cramer's V for categorical variables

Table 2.3 Distribution of variables by trajectory group of hyperactivity/inattention (unweighted data)

	Total N = 12,589	Range	1. Deteriorating N = 1,007	2. Improving N = 1,629	3. Typically developing N = 7,939	4. High risk N = 756	p-value	Effect size
Continuous variables, M (SD)								*Eta-Squared*
SWM errors	35.27 (18.65)	[0,173]	39.20 (18.27)	39.04 (18.50)	33.17 (18.30)	43.99 (18.55)	< 0.001	.03
SWM strategy	34.22 (5.90)	[0,48]	34.88 (5.66)	35.13 (5.43)	33.79 (6.00)	35.82 (5.65)	< 0.001	.01
Age in months	133.44 (3.99)	[120,147.96]	133.06 (4.02)	133.47 (3.97)	133.50 (3.96)	133.25 (4.17)	0.005	.00
Poverty	0.27 (0.36)	[0,1]	0.33 (0.38)	0.41 (0.40)	0.22 (0.34)	0.42 (0.39)	< 0.001	.05
Maternal depression	0.21 (0.31)	[0,1]	0.28 (0.34)	0.33 (0.36)	0.16 (0.28)	0.42 (0.38)	< 0.001	.07
Verbal ability	58.89 (9.85)	[20,80]	56.87 (10.15)	56.23 (10.24)	60.12 (9.22)	54.23 (11.91)	< 0.001	.04
Categorical variables, n (%)								*Cramer's V*
Female	5,660 (50%)	\	427 (42%)	707 (43%)	4,309 (54%)	217 (29%)	< 0.001	.15
Mixed	300 (3%)	\	24 (2%)	54 (3%)	199 (3%)	23 (3%)	< 0.001	.02
Indian	266 (2%)	\	20 (2%)	54 (3%)	178 (2%)	14 (2%)	< 0.001	.03
Pakistani and Bangladeshi	671 (6 %)	\	77 (8%)	160 (10%)	389 (5%)	45 (6%)	< 0.001	.08
Black or Black British	302 (3%)	\	21 (2%)	39 (2%)	227 (3%)	15 (2%)	< 0.001	.02
Other (Inc Chinese)	141 (1%)	\	9 (1%)	32 (2%)	94 (1%)	6 (1%)	< 0.001	.03
Mother has 1st degree	2,109 (19%)	\	136 (14%)	154 (10%)	1,761 (23%)	58 (8%)	< 0.001	.14

Total number includes 1,258 individuals with missing value on group membership.
p-values for between group F-tests for continuous variables and chi-square tests for categorical variables
Effect size: Eta-Squared for continuous variables and Cramer's V for categorical variables

Table 3 Regression estimates [coefficients (SE)] of internalising problem group membership on SWM total errors

	Model 1	Model 2	Model 3	Model 4
Internalising Behaviours (Ref: No risk)				
Deteriorating	4.69 (0.89) ***	4.23 (0.89) ***	3.09 (0.89) ***	2.60 (0.92) **
Low risk	3.14 (0.51) ***	3.19 (0.51) ***	1.76 (0.50) ***	1.33 (0.50) **
High risk	7.15 (0.56) ***	7.03 (0.55) ***	4.30 (0.62) ***	3.09 (0.60) ***
Age at Sweep 5		-0.31 (0.06) ***	-0.32 (0.06) ***	-0.35 (0.05) ***
Gender (Ref: Male)				
Female		-1.10 (0.39) **	-1.16 (0.37) **	-1.33 (0.37) ***
Poverty			6.14 (0.63) ***	4.58 (0.66) ***
Ethnicity (Ref: White)				
Mixed			0.76 (1.38)	1.23 (1.37)
Indian			-0.02 (1.57)	0.98 (1.62)
Pakistani and Bangladeshi			0.86 (0.92)	0.42 (1.06)
Black or Black British			5.48 (1.54) ***	6.23 (1.48) ***
Other (Inc Chinese)			-2.70 (1.74)	-2.31 (1.76)
Maternal Education				
Has 1st degree			-6.10 (0.54) ***	-4.85 (0.56) ***
Maternal Depression			1.00 (0.79)	1.09 (0.76)
Verbal ability				-0.32 (0.02) ***
Constant	33.15 (0.33) ***	74.96 (7.57) ***	76.31 (7.43) ***	98.75 (6.97) ***

*p< 0.05; **p<0.01; ***p<0.001
Model 1: Group membership of problem behaviours
Model 2: Model 1 + Age + Gender
Model 3: Model 2 + Poverty + Ethnicity + Maternal Education + Maternal Depression
Model 4: Model 3 + Verbal Ability (Verbal Similarities at age 11)

Table 4 Regression estimates [coefficients (SE)] of internalising problem group membership on SWM strategy

	Model 1	Model 2	Model 3	Model 4
Internalising Behaviours (Ref: No risk)				
Deteriorating	0.81 (0.30) **	0.73 (0.30) *	0.45 (0.30)	0.36 (0.30)
Low risk	0.69 (0.15) ***	0.71 (0.15) ***	0.37 (0.15) *	0.29 (0.15)
High risk	1.13 (0.19) ***	1.13 (0.19) ***	0.48 (0.19) *	0.29 (0.20)
Age at Sweep 5		-0.06 (0.02) ***	-0.06 (0.02) ***	-0.09 (0.02) ***
Gender (Ref: Male)				
Female		0.13 (0.13)	0.12 (0.12)	0.06 (0.12)
Poverty			1.08 (0.19) ***	0.69 (0.19) ***
Ethnicity (Ref: White)				
Mixed			0.01 (0.38)	0.09 (0.38)
Indian			-0.45 (0.53)	-0.19 (0.53)
Pakistani and Bangladeshi			0.53 (0.29)	0.40 (0.31)
Black or Black British			0.88 (0.37) *	1.00 (0.35) **
Other (Inc Chinese)			-0.79 (0.60)	-0.66 (0.63)
Maternal Education				
Has 1st degree			-1.82 (0.19) ***	-1.50 (0.21) ***
Maternal Depression			0.37 (0.22)	0.41 (0.21)
Verbal ability				-0.08 (0.01) ***
Constant	33.85 (0.10) ***	41.82 (2.34) ***	42.30 (2.30) ***	50.40 (2.24) ***

*p< 0.05; **p<0.01; ***p<0.001
Model 1: Group membership of problem behaviours
Model 2: Model 1 + Age + Gender
Model 3: Model 2 + Poverty + Ethnicity + Maternal Education + Maternal Depression
Model 4: Model 3 + Verbal Ability (Verbal Similarities at age 11)

Table 5 Regression estimates [coefficients (SE)] of conduct problem group membership on SWM total errors

	Model 1	Model 2	Model 3	Model 4
Conduct Problems (Ref: Early childhood limited)				
Deteriorating	2.13 (1.14)	1.81 (1.15)	1.06 (1.12)	0.50 (1.10)
Improving	3.70 (0.55) ***	3.66 (0.55) ***	1.93 (0.55) ***	1.38 (0.52) **
High risk	7.03 (0.64) ***	6.76 (0.63) ***	4.23 (0.70) ***	3.25 (0.66) ***
Age at Sweep 5		-0.30 (0.06) ***	-0.32 (0.06) ***	-0.35 (0.05) ***
Gender (Ref: Male)				
Female		-0.80 (0.39) *	-0.96 (0.37) *	-1.18 (0.37) **
Poverty			5.99 (0.64) ***	4.45 (0.66) ***
Ethnicity (Ref: White)				
Mixed			0.94 (1.38)	1.36 (1.36)
Indian			0.58 (1.57)	1.42 (1.63)
Pakistani and Bangladeshi			1.72 (0.91)	1.05 (1.06)
Black or Black British			5.86 (1.48) ***	6.50 (1.43) ***
Other (Inc Chinese)			-2.32 (1.71)	-2.04 (1.72)
Maternal Education				
Has 1st degree			-6.10 (0.56) ***	-4.85 (0.58) ***
Maternal Depression			1.33 (0.77)	1.31 (0.74)
Verbal ability				-0.32 (0.02) ***
Constant	33.88 (0.32) ***	74.93 (7.64) ***	76.48 (7.46) ***	99.06 (7.00) ***

*p< 0.05; **p<0.01; ***p<0.001

Model 1: Group membership of problem behaviours

Model 2: Model 1 + Age + Gender

Model 3: Model 2 + Poverty + Ethnicity + Maternal Education + Maternal Depression

Model 4: Model 3 + Verbal Ability (Verbal Similarities at age 11)

Table 6 Regression estimates [coefficients (SE)] of conduct problem group membership on SWM strategy

	Model 1	Model 2	Model 3	Model 4
Conduct Problems (Ref: Early childhood limited)				
Deteriorating	0.89 (0.32) **	0.84 (0.32) **	0.66 (0.31) *	0.49 (0.30)
Improving	0.79 (0.17) ***	0.80 (0.17) ***	0.42 (0.17) *	0.33 (0.16) *
High risk	1.40 (0.22) ***	1.40 (0.22) ***	0.84 (0.23) ***	0.70 (0.21) **
Age at Sweep 5		-0.06 (0.02) **	-0.06 (0.02) **	-0.09 (0.02) ***
Gender (Ref: Male)				
Female		0.20 (0.13)	0.17 (0.12)	0.11 (0.12)
Poverty			1.01 (0.18) ***	0.62 (0.18) ***
Ethnicity (Ref: White)				
Mixed			0.02 (0.38)	0.09 (0.38)
Indian			-0.34 (0.53)	-0.11 (0.54)
Pakistani and Bangladeshi			0.67 (0.29) *	0.51 (0.30)
Black or Black British			0.96 (0.36) **	1.06 (0.35) **
Other (Inc Chinese)			-0.72 (0.61)	-0.60 (0.63)
Maternal Education				
Has 1st degree			-1.82 (0.19) ***	-1.51 (0.21) ***
Maternal Depression			0.32 (0.21)	0.34 (0.21)
Verbal ability				-0.08 (0.01) ***
Constant	33.93 (0.09) ***	41.42 (2.32) ***	41.95 (2.28) ***	49.98 (2.23) ***

*p< 0.05; **p<0.01; ***p<0.001

Model 1: Group membership of problem behaviours

Model 2: Model 1 + Age + Gender

Model 3: Model 2 + Poverty + Ethnicity + Maternal Education + Maternal Depression

Model 4: Model 3 + Verbal Ability (Verbal Similarities at age 11)

Table 7 Regression estimates [coefficients (SE)] of hyperactivity/inattention group membership on SWM total errors

	Model 1	Model 2	Model 3	Model 4
Hyperactivity/inattention (Ref: Typically developing)				
Deteriorating	5.68 (0.72) ***	5.49 (0.73) ***	4.31 (0.70) ***	3.59 (0.71) ***
Improving	5.55 (0.59) ***	5.50 (0.59) ***	3.55 (0.60) ***	2.88 (0.59) ***
High risk	10.04 (0.87) ***	9.81 (0.86) ***	7.63 (0.92) ***	5.80 (0.80) ***
Age at Sweep 5		-0.30 (0.06) ***	-0.31 (0.05) ***	-0.34 (0.05) ***
Gender (Ref: Male)				
Female		-0.39 (0.39)	-0.59 (0.38)	-0.88 (0.37) *
Poverty			5.92 (0.62) ***	4.44 (0.65) ***
Ethnicity (Ref: White)				
Mixed			0.93 (1.38)	1.32 (1.36)
Indian			0.47 (1.56)	1.28 (1.62)
Pakistani and Bangladeshi			1.53 (0.94)	0.92 (1.07)
Black or Black British			6.01 (1.50) ***	6.59 (1.44) ***
Other (Inc Chinese)			-1.94 (1.67)	-1.77 (1.69)
Maternal Education				
Has 1st degree			-5.84 (0.56) ***	-4.68 (0.58) ***
Maternal Depression			0.82 (0.76)	0.90 (0.74)
Verbal ability				-0.31 (0.02) ***
Constant	33.55 (0.29) ***	73.70 (7.55) ***	74.78 (7.36) ***	96.65 (7.02) ***

*p< 0.05; **p<0.01; ***p<0.001

Model 1: Group membership of problem behaviours

Model 2: Model 1 + Age + Gender

Model 3: Model 2 + Poverty + Ethnicity + Maternal Education + Maternal Depression

Model 4: Model 3 + Verbal Ability (Verbal Similarities at age 11)

Table 8 Regression estimates [coefficients (SE)] of hyperactivity/inattention group membership on SWM strategy

	Model 1	Model 2	Model 3	Model 4
Hyperactivity/inattention (Ref: Typically developing)				
Deteriorating	1.10 (0.23) ***	1.10 (0.23) ***	0.82 (0.22) ***	0.63 (0.23) **
Improving	1.25 (0.18) ***	1.27 (0.18) ***	0.82 (0.19) ***	0.65 (0.19) ***
High risk	1.67 (0.25) ***	1.70 (0.25) ***	1.19 (0.26) ***	1.06 (0.24) ***
Age at Sweep 5		-0.06 (0.02) **	-0.06 (0.02) **	-0.09 (0.02) ***
Gender (Ref: Male)				
Female		0.27 (0.13) *	0.22 (0.12)	0.16 (0.12)
Poverty			1.00 (0.19) ***	0.63 (0.19) ***
Ethnicity (Ref: White)				
Mixed			0.01 (0.38)	0.07 (0.38)
Indian			-0.38 (0.52)	-0.15 (0.53)
Pakistani and Bangladeshi			0.61 (0.29) *	0.47 (0.31)
Black or Black British			0.98 (0.36) **	1.07 (0.35) **
Other (Inc Chinese)			-0.66 (0.60)	-0.56 (0.62)
Maternal Education				
Has 1st degree			-1.78 (0.19) ***	-1.48 (0.21) ***
Maternal Depression			0.26 (0.22)	0.28 (0.21)
Verbal ability				-0.07 (0.01) ***
Constant	33.90 (0.08) ***	41.40 (2.33) ***	41.84 (2.28) ***	49.73 (2.21) ***

*p< 0.05; **p<0.01; ***p<0.001

Model 1: Group membership of problem behaviours

Model 2: Model 1 + Age + Gender

Model 3: Model 2 + Poverty + Ethnicity + Maternal Education + Maternal Depression

Model 4: Model 3 + Verbal Ability (Verbal Similarities at age 11)

Total number of families
participating in MCS
N = 19,244

⇩

Participating children at MCS2 (age 3), MCS3 (age 5), MCS4 (age 7) and MCS5 (age 11)
N = 15,808, N = 15,460, N = 14,043, N = 13,469

⇩

Singletons and first-born twins or triplets at MCS2, MCS3, MCS4 and MCS5
N=15,591 N= 15,247 N= 13,857 N=13,287

⇩

| Children with at least two ratings on internalising problems N = 14,226 | Children with at least two ratings on conduct problems N = 14,242 | Children with at least two ratings on hyperactivity/inattention N = 14,249 |
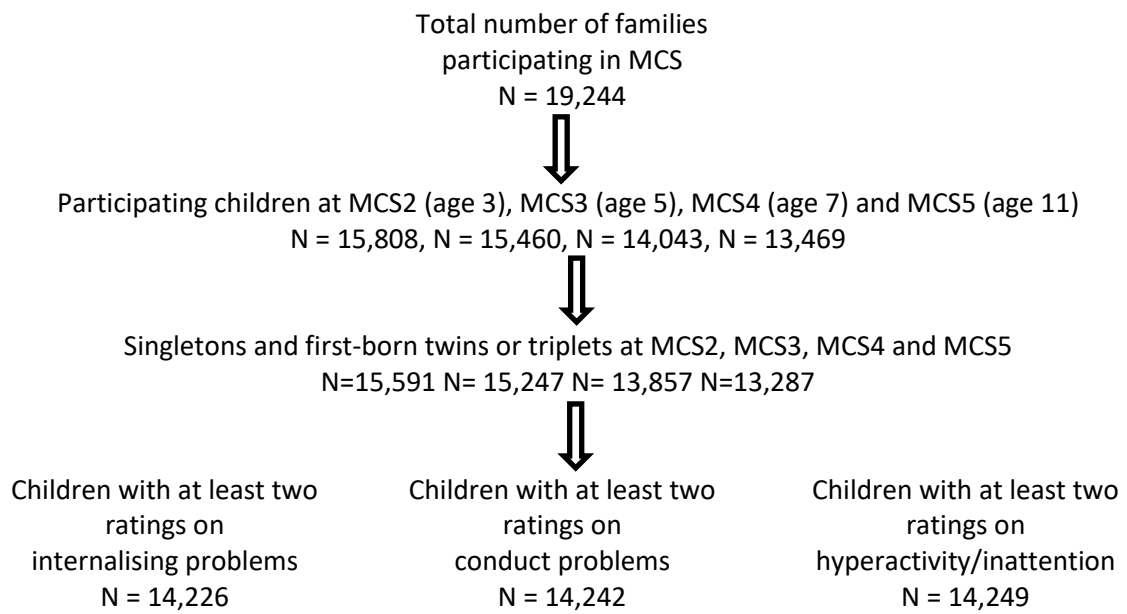
Figure 1 Analytic samples for GBTM

Total number of families
participating in MCS
N = 19,244

⇩

Participating children at MCS5
(age 11)
N = 13,469

⇩

Singletons and first-born twins
or triplets
N = 13,287

⇩

Children with complete data on
SWM
N = 12,589
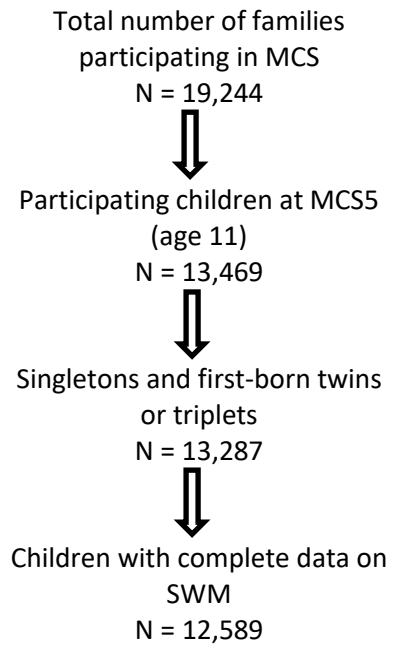
Figure 2 Analytic sample for multiple regression analyses
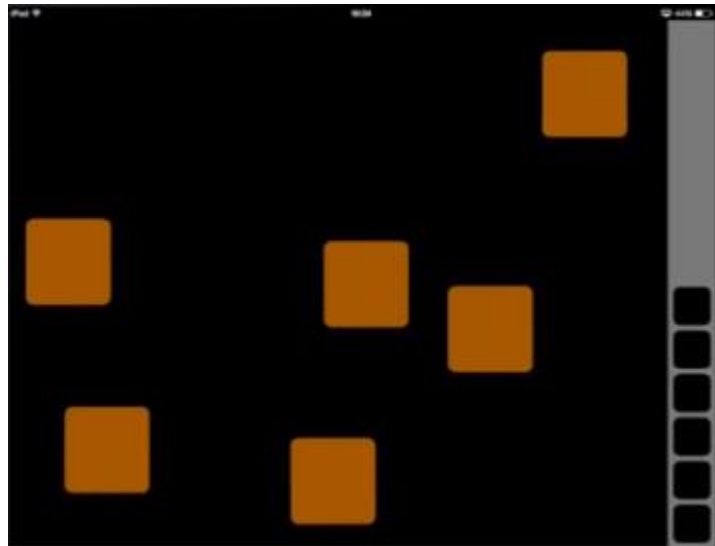
Figure 3 An example of the SWM task on a screen
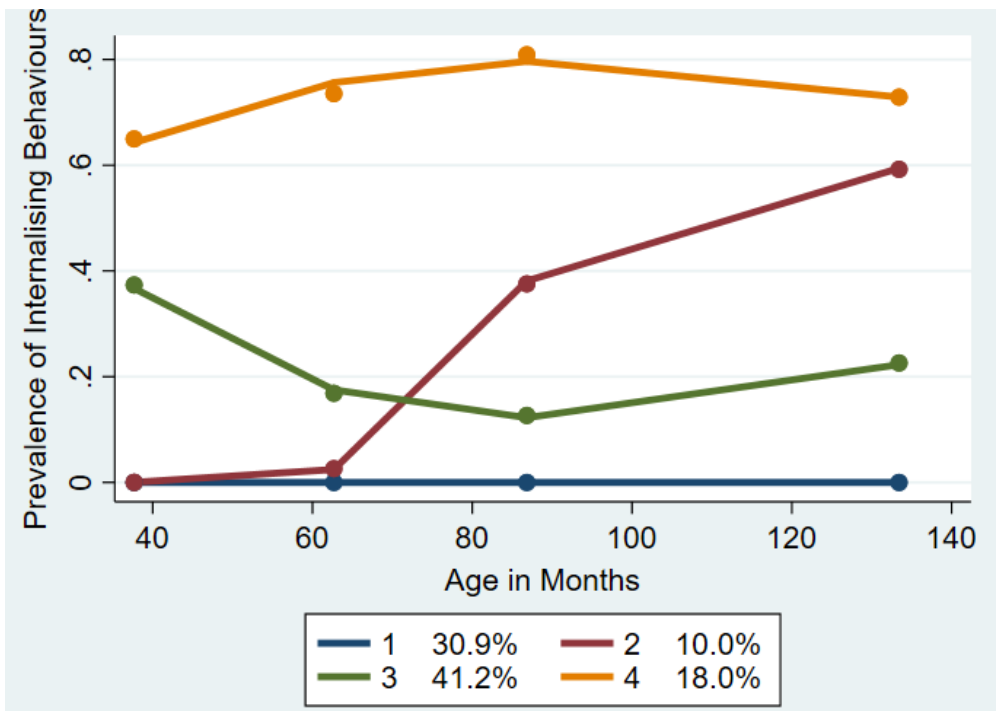
Figure 4 Trajectory groups of internalising problems from ages 3 to 11 years. Shown are estimated trajectories (solid lines), observed group means at each age (dot symbols), and estimated group percentages. 1 – No risk group, 2 – Deteriorating group, 3 – Low risk group, 4 – High risk group.
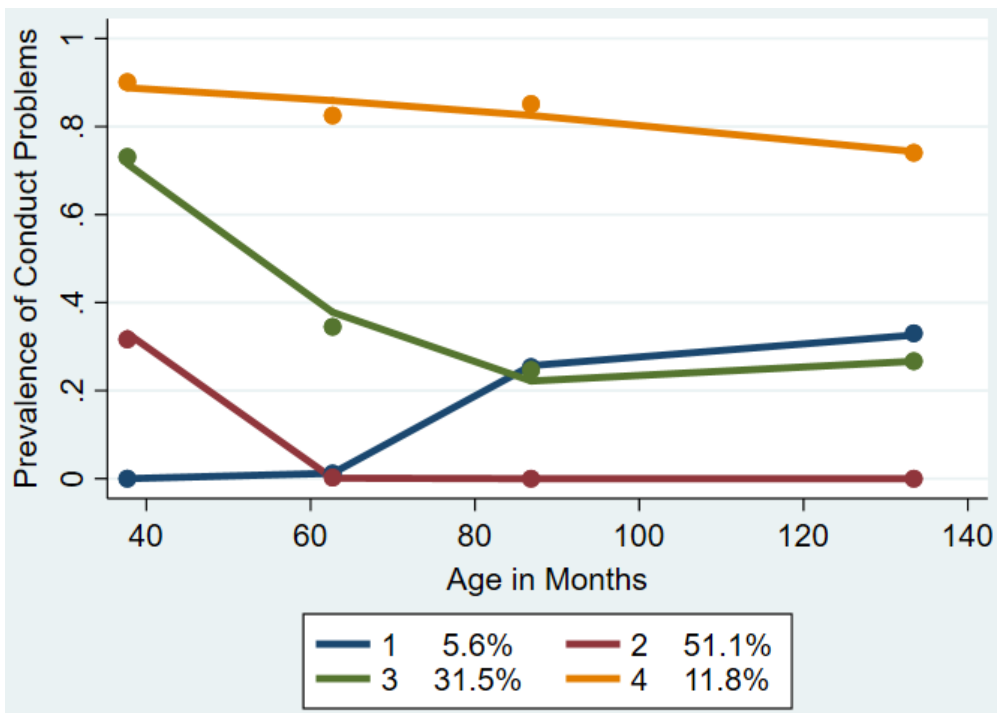
Figure 5 Trajectory groups of conduct problems from ages 3 to 11 years. Shown are estimated trajectories (solid lines), observed group means at each age (dot symbols), and estimated group percentages. 1 – Deteriorating group, 2 – Early childhood-limited group, 3 – Improving group, 4 – High risk group.
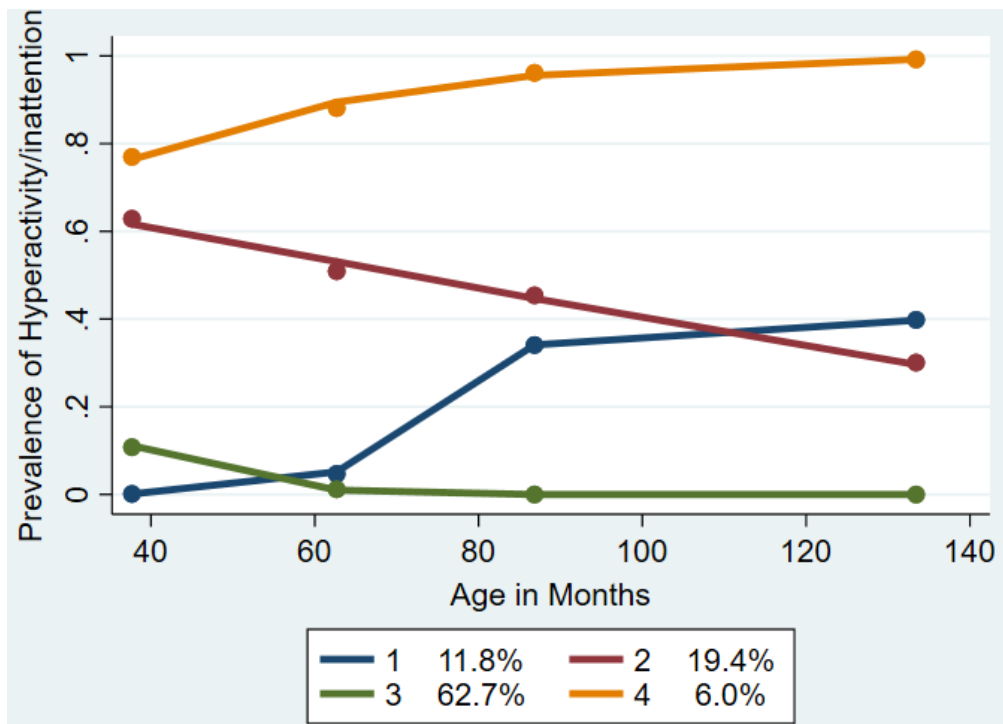
Figure 6 Trajectory groups of hyperactivity/inattention from ages 3 to 11 years. Shown are estimated trajectories (solid lines), observed group means at each age (dot symbols), and estimated group percentages. 1 – Deteriorating group, 2 – Improving group, 3 – Typically developing group, 4 – High risk group.

Supplementary Material

Tables S1.1/S1.2/S1.3 present the fit indices of the 2- to 6-group solutions of GBTM applied to examine the developmental trajectories of internalising problems, conduct problems and hyperactivity/inattention from ages 3 to 11 years.

Tables S2.1/S2.2/S2.3 present the fit indices of the 4-group solution of GBTM applied to examine the shapes of the developmental trajectories of internalising problems, conduct problems and hyperactivity/inattention from ages 3 to 11 years.

Table S1.1 Fit indices of the 2- to 6-group solutions for internalising problems

Number of Groups	BIC (N*=50778)	BIC (N*=14226)	AvePP	OCC	P	Π_j	The Highest Order Coefficient Significant
2	-26192.62	-26188.17	.92	4.70	.73	.70	Y
			.86	15.10	.27	.30	Y
3	-26150.84	-26143.84	.82	5.58	.33	.45	Y
			.71	3.78	.53	.40	N
			.76	18.14	.14	.15	Y
4	-26115.09	-26105.55	.64	3.95	.48	.31	N
			.53	11.00	.06	.09	Y
			.75	4.36	.30	.41	Y
			.82	19.43	.17	.19	Y
5	-26132.82	--26120.73	N/A	N/A	N/A	N/A	N
			.54	15.73	.03	.07	N
			.74	3.90	.32	.42	Y
			.62	3.79	.48	.30	Y
			.82	19.32	.17	.19	Y
6+	-26144.71	-26130.08	.53	12.31	.06	.08	Y
			N/A	N/A	N/A	N/A	Y
			.70	3.98	.30	.37	Y
			.67	4.03	.48	.33	Y
			N/A	N/A	N/A	N/A	N
			.80	18.69	.17	.18	Y

*The smaller N pertains to the number of individuals in the estimation sample. The larger sample size counts the total number of assessments used in model estimation across persons and time.

+variance matrix is nonsymmetric or highly singular

Table S1.2 Fit indices of the 2- to 6-group solutions for conduct problems

Number of Groups	BIC (N*=50918)	BIC (N*=14242)	AvePP	OCC	P	Π_j	The Highest Order Coefficient Significant
2	-25715.21	-25710.75	.89	5.77	.65	.59	Y
			.99	139.40	.35	.41	Y
3	-25570.45	-25563.45	.74	10.84	.04	.21	N
			.67	2.48	.66	.45	N
			.94	30.30	.30	.34	Y
4	-25480.53	-25470.97	.56	21.99	.03	.06	Y
			.78	7.26	.20	.32	Y
			.76	3.22	.65	.50	Y
			.73	19.34	.12	.12	N
5+	-25495.15	-25483.04	.56	22.53	.03	.05	N/A
			.82	9.31	.40	.33	N/A
			.78	7.40	.20	.33	N/A
			.63	8.88	.24	.16	N/A
			.73	18.99	.12	.12	N/A
6+	-25516.82	-25502.17	.82	9.31	.40	.33	N/A
			.56	22.50	.03	.05	N/A
			.63	8.88	.24	.16	N/A
			.78	7.40	.20	.33	N/A
			N/A	N/A	N/A	N/A	N/A
			.73	18.98	.12	.12	N/A

*The smaller N pertains to the number of individuals in the estimation sample. The larger sample size counts the total number of assessments used in model estimation across persons and time.

+ variance matrix is nonsymmetric or highly singular

Table S1.3 Fit indices of the 2- to 6-group solutions for hyperactivity/inattention

Number of Groups	BIC (N*=50920)	BIC (N*=14249)	AvePP	OCC	P	Π_j	The Highest Order Coefficient Significant
2	-21725.90	-21721.44	.93	7.05	.69	.65	Y
			.96	50.07	.31	.35	Y
3	-21438.03	-21431.03	.79	22.42	.08	.15	Y
			.86	3.63	.73	.63	Y
			.94	51.19	.19	.22	N
4	-21375.33	-21365.78	.81	4.11	.61	.51	N
			.63	17.16	.08	.09	Y
			.77	9.54	.18	.26	Y
			.84	33.55	.13	.14	Y
5+	-21384.57	-21372.48	.89	5.36	.67	.61	Y
			.67	104.01	.02	.02	N
			.50	21.73	.01	.04	N
			.64	6.68	.19	.21	Y
			.79	29.11	.11	.12	Y
6	-21389.01	-21374.36	.64	102.18	.02	.02	N
			.76	2.83	.67	.52	Y
			.59	134.24	.01	.01	Y
			.72	9.94	.10	.21	Y
			.76	15.48	.13	.17	N
			.71	34.57	.08	.07	Y

*The smaller N pertains to the number of individuals in the estimation sample. The larger sample size counts the total number of assessments used in model estimation across persons and time.

+variance matrix is nonsymmetric or highly singular

Tables S2.1 Fit indices of the 4-group solution of GBTM applied to examine the shapes of the developmental trajectories of internalising problems

Model	BIC (N*=50778)	BIC (N*=14226)	AvePP	OCC	P	*IIj*	The Highest Order Coefficient Significant
0222	-26110.35	-26102.08	.61	3.84	.47	.29	Y
			.54	10.62	.06	.10	Y
			.77	4.63	.29	.42	Y
			.83	20.11	.18	.20	Y
2222	-26115.09	-26105.55	.64	3.95	.48	.31	N
			.53	11.00	.06	.09	Y
			.75	4.36	.30	.41	Y
			.82	19.43	.17	.19	Y
1222	-26115.77	-26106.86	.61	3.84	.47	.29	N
			.54	10.62	.06	.10	Y
			.77	4.63	.29	.42	Y
			.83	20.11	.18	.20	Y
1122	-26122.11	-26113.84					
2102	-26122.47	-26114.84					
2012	-26122.47	-26114.84					
2221	-26124.33	-26115.43					
2202	-26124.68	-26116.41					
2122	-26126.87	-26117.97					
2212	-26126.87	-26117.97					
2022	-26127.00	-26118.73					
0212	-26127.27	-26119.64					
0221+	-26127.27	-26119.64					
1221	-26127.59	-26119.32					
1212	-26127.59	-26119.32					
1220	-26128.55	-26120.91					
2111	-26130.13	-26122.50					
1202	-26131.87	-26124.23					
2201	-26133.04	-26125.41					
2021	-26133.04	-26125.41					
2120	-26133.48	-26125.84					
2210	-26133.48	-26125.84					
2220	-26133.97	-26125.70					
1121	-26136.58	-26128.94					
1211	-26136.99	-26129.36					
2211	-26141.66	-26133.39					
2121	-26141.86	-26133.59					
0122	-26142.22	-26134.58					
1112	-26149.10	-26141.46					
1022	-26150.07	-26142.44					
1111	-26159.61	-26152.61					
2112+	-26169.29	-26161.01					

*The smaller N pertains to the number of individuals in the estimation sample. The larger sample size counts the total number of assessments used in model estimation across persons and time.

+variance matrix is nonsymmetric or highly singular

In total 32 combination tested including four groups all set as either quadratic or linear (16 combinations e.g., 1221) AND one group set as constant while three other groups are quadratic or linear (16 combinations e.g., 1021)

Tables S2.2 Fit indices of the 4-group solution of GBTM applied to examine the shapes of the developmental trajectories of conduct problems

Model	BIC (N*=50918)	BIC (N*=14242)	AvePP	OCC	P	Πj	The Highest Order Coefficient Significant
2221	-25475.13	-25466.21	.56	22.11	.03	.05	Y
			.76	3.21	.65	.50	Y
			.78	7.39	.20	.32	Y
			.73	18.47	.13	.13	Y
2220+	-25477.24	-25468.96	.90	14.38	.42	.39	Y
			.87	12.13	.26	.35	Y
			.71	10.94	.25	.19	N
			.72	32.29	.07	.07	Y
2212+	-25479.89	-25470.97	.79	7.29	.25	.34	Y
			.89	12.93	.42	.28	Y
			.78	29.95	.08	.10	Y
			.68	9.80	.25	.18	N
2222	-25480.53	-25470.97	.56	21.99	.03	.06	Y
			.78	7.26	.20	.32	Y
			.76	3.22	.65	.50	Y
			.73	19.34	.12	.12	N
1220+	-25483.91	-25476.27	.91	15.37	.42	.40	Y
			.73	11.38	.25	.19	N
			.87	12.49	.26	.34	Y
			.68	31.14	.06	.07	Y
1202	-25487.57	-25479.92					
2120	-25487.57	-25479.92					
1212	-25491.43	-25483.15					
2112	-25491.43	-25483.15					
0221+	-25498.12	-25490.48					
0202	-25498.81	-25491.80					
2020	-25503.07	-25496.06					
2201	-25511.26	-25503.61					
0212	-25516.10	-25508.46					
1022	-25519.80	-25512.16					
0022	-25521.62	-25514.62					
2021	-25523.54	-25515.89					
2122	-25523.79	-25514.87					
1122+	-25523.98	-25515.70					
1221+	-25526.82	-25518.54					
1112	-25528.85	-25521.20					
2202+	-25532.69	-25524.40					
2200	-25558.94	-25551.93					
0220	-25561.62	-25554.62					
2022	-25572.08	-25563.80					
0222	-25572.91	-25564.63					
0122	-25575.22	-25567.57					
2210	-25581.31	-25573.66					
1222+	-25586.05	-25577.14					
2102	-25603.05	-25595.41					
2012	-25658.54	-25650.90					
1121	-25697.13	-25689.49					
1111+	-25704.18	-25697.17					
2121	-25706.99	-25698.70					
1211+	-25709.60	-25701.95					
2111+	-25709.60	-25701.95					
2002	-25794.68	-25787.67					
2211+	-25869.78	-25861.50					

*The smaller N pertains to the number of individuals in the estimation sample. The larger sample size counts the total number of assessments used in model estimation across persons and time.

+variance matrix is nonsymmetric or highly singular

In total 38 combinations tested including four groups all set as either quadratic or linear (16 combinations e.g., 1221) AND one or two groups set as constant while other groups are quadratic or linear (22 combinations e.g., 1021; 2021)

Tables 2.3 Fit indices of the 4-group solution of GBTM applied to examine the shapes of the developmental trajectories of hyperactivity/inattention

Model	BIC (N*=50920)	BIC (N*=14249)	AvePP	OCC	P	Πj	The Highest Order Coefficient Significant
1222	-21369.67	-21360.75	.83	4.15	.63	.54	Y
			.56	26.48	.05	.05	Y
			.84	14.30	.18	.27	Y
			.84	30.64	.14	.14	Y
2122	-21369.67	-21360.75	.56	26.48	.05	.05	Y
			.83	4.15	.63	.54	Y
			.84	14.30	.18	.27	Y
			.84	30.64	.14	.14	Y
2121	-21374.52	-21366.24	.71	18.75	.08	.12	Y
			.80	15.94	.15	.20	Y
			.86	3.88	.70	.61	Y
			.72	37.14	.07	.06	Y
2222	-21375.33	-21365.78	.81	4.11	.61	.51	N
			.63	17.16	.08	.09	Y
			.77	9.54	.18	.26	Y
			.84	33.55	.13	.14	Y
2221	-21378.72	-21369.81	.73	19.39	.08	.12	Y
			.86	3.83	.70	.61	Y
			.80	15.84	.15	.20	N
			.72	37.31	.07	.06	Y
2220	-21387.07	-21378.79					
2021	-21391.97	-21384.33					
2020	-21394.06	-21387.05					
0212	-21403.41	-21395.77					
2012+	-21418.57	-21410.93					
2022	-21419.22	-21410.94					
0222	-21421.91	-21413.63					
2102	-21423.25	-21415.61					
1202	-21423.25	-21415.61					
1122	-21423.99	-21415.71					
1112	-21424.18	-21416.54					
2002	-21426.30	-21419.30					
0022	-21426.31	-21419.30					
1121	-21428.86	-21421.22					
2112+	-21429.60	-21421.32					
1212	-21429.61	-21421.33					
2200	-21432.00	-21424.99					
2212+	-21435.00	-21426.08					
2202	-21437.14	-21428.86					
2120	-21437.26	-21429.62					
1111	-21439.17	-21432.17					
1211+	-21444.59	-21436.95					
2111+	-21444.59	-21436.95					
1221+	-21447.98	-21439.70					
1220+	-21450.71	-21443.07					
0220+	-21451.46	-21444.45					
0202	-21452.15	-21445.15					
0221+	-21453.51	-21445.86					
0122+	-21457.15	-21449.51					
1022	-21457.36	-21449.72					
2210+	-21629.48	-21621.84					
2211+	-21632.78	-21624.50					
2201+	-21749.89	-21742.25					

*The smaller N pertains to the number of individuals in the estimation sample. The larger sample size counts the total number of assessments used in model estimation across persons and time.

+variance matrix is nonsymmetric or highly singular

In total 38 combination tested including four groups all set as either quadratic or linear (16 combinations e.g., 1221) AND one or two groups set as constant while other groups are quadratic or linear (22 combinations e.g., 1021; 2021)