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

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Declaration

I, Ye Kuang, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

Spatial working memory is strongly related to cognitive ability and has an impact on children's learning. The development of child and adolescent psychopathology affects cognitive outcomes, but there is limited research on its effects on spatial working memory in specific. The present study aimed to explore whether young adolescents' spatial working memory differs across different childhood psychopathology trajectories in terms of internalising problems, conduct problems, and hyperactivity / inattention. The final sample of this secondary analysis study consisted of 12,589 children around 11 years old from the UK's Millennium Cohort Study. Two stages of data analysis were conducted. Trajectory groups were firstly estimated by Group Based Trajectory Modelling for internalising problems (N = 14,226), conduct problems (N = 14,242), and hyperactivity / inattention (N = 14,249), respectively following children from the age of 3 years to the age of 11 years. Multiple regressions were then adopted to assess the relationship between spatial working memory and trajectory group membership of childhood psychopathology. Results showed that trajectories of child psychopathology were related to 11-year-olds' spatial working memory even after controlling for confounding variables. In general, children with higher probabilities of developing atypical internalising problems, conduct problems, and hyperactivity / inattention seemed more likely to show less competent spatial working memory at age 11. The subsequent data analysis with a sub-sample (N = 7147) further revealed, via less competent spatial working memory, higher risks of child psychopathology symptoms were associated with lower teacher-reported ratings on

children's academic performance in English, maths, and science. Finally, the present study investigated the implications of the link between child psychopathology and spatial working memory for practice in the field of educational psychology via an online survey.

Impact Statement

The present study, as the first to our knowledge, demonstrated the relationships between young adolescents' spatial working memory and the developmental course of a broad range of behavioural and emotional symptoms across childhood. Children at risk of atypical development in behavioural and emotional symptoms, especially the chronic type, showed less competent spatial working memory, which in turn was associated with lower ratings on teacher-reported academic performance in English, maths, and science.

These findings have important implications for the research in fields of education and psychology. The findings provided some evidence for research that suggested a link between executive functioning impairments and Attention Deficit Hyperactivity Disorder (e.g., Schoemaker et al., 2013; Willcutt et al., 2005). The findings highlighted that children might simultaneously present with a chronic type of problem behaviour(s), cognitive needs, and poor academic performance under the impact of childhood trauma or adverse childhood experiences (Van der Kolk, 2015). The findings also have important implications for real-life practice. According to the feedback from educational psychology professionals who are supporting children with learning difficulties and / or social emotional mental health needs (see Section 7.4), the link between atypical development in behavioural and emotional symptoms and impairments in spatial working memory could offer new ideas in multiple areas of work including hypothesis formulation, assessment, intervention, consultation, and systemic work. The link could also support children's important others e.g., parents, teachers, and school in understanding children's problem

behaviours, acting as advocates, and being motivated to adopt a positive approach in interacting with these children, all of which contribute to positive outcomes for children's development (Carroll & Hurry, 2018).

Further research could investigate whether the associations the present study found are causal, and if so, what direction, or whether they are due to common causes using randomized experiments. This is an important issue because establishing causality will have profound effects on planning both prevention and intervention strategies for poor spatial working memory, in turn, a strong predictor of low academic performance and educational attainment.

Definition of Terms

In the context of the current study:

Academic performance is, in a school context, one's performance on "academic achievement, the accomplishment of learning objectives, and acquisition of skills and competencies" (York et al., 2019, p. 7).

Child psychopathology means children's adaptational difficulty or areas of needs caused by atypical mental health development. Child psychopathology could be manifested by social emotional and / or mental health needs (including behaviour) including becoming withdrawn or isolated, displaying challenging, disruptive, or disturbing behaviours, and mental health disorders such as attention deficit disorder, attention deficit hyperactive disorder, or attachment disorder. Child psychopathology could be commonly grouped into internalising problems / overcontrolled problems and externalising problems / under-controlled problems.

Cognitive ability is a general mental capability involving reasoning, problem-solving, planning, abstract thinking, complex idea comprehension, and learning from experience (Gottfredson, 1997). Cognitive ability is a strong predictor of academic and job performance.

Externalising problems are one type of child psychopathology that is based on under-controlled symptoms such as hyperactivity, conduct problems, and antisocial behaviours.

Executive functions are top-down cognitive abilities that are required to concentrate and pay attention in novel situations, where relying on previous experiences or instinct would

be insufficient or impossible. Core executive functions include inhibition, working memory, and cognitive flexibility (Diamond, 2013).

Internalising problems are one type of child psychopathology that is based on overcontrolled symptoms such as anxiety, depression, social withdrawal, and somatic complaints without apparent medical reasons.

Spatial working memory (SWM) is a specific type of working memory involving the holding and working with visual / spatial information using some of the executive functions during complex cognitive activities. In the context of the multicomponent model (Baddeley, 2021), SWM could involve the visuospatial sketchpad, the episodic buffer, and the central executive.

Working memory refers to the cognitive processes that hold information (e.g., information storage and maintenance), and work with information (e.g., information coding and combination) using some of the executive functions (e.g., effortful control of attention) during complex cognitive activities including learning and responding to novel situations.

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Chapter 1

Background and The Research Questions

Spatial Working Memory (SWM) is defined as the cognitive ability to manipulate spatial-visual information during complex cognitive activities (Logie, 2009). SWM, also recognised as visual-spatial working memory, plays an essential role in short-term memory and long-term verbal memory that uses spatial mnemonics (Baddeley & Lieberman, 1980 cited in Baddeley, 2017). Reduced SWM capacity is associated with difficulties in cognitive activities, including mathematics learning (Aronen et al., 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 et al. (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 for confounding variables.

The impact of children's psychopathology symptoms on their later SWM, if identified by the present study, could be explained from neuroscience and cognitive psychology perspectives. On the one hand, neuroscience 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 et al., 1996; Taverniers et al., 2010; Zahrt et al., 1997). Given that internalising and externalising problems, especially of the chronic type, are also associated with dysregulated dopamine and cortisol levels in the hypothalamic-pituitary-adrenal (HPA) system (Capaldi et al., 2012; Ruttle et al., 2011; Zahn–Waxler et al., 2000), children with atypical internalising and / or externalising symptoms may show poor SWM because prefrontal cortical dopaminergic dysfunction or cortisol-related HPA axis dysregulation causes both.

On the other hand, some cognitive psychological theories such as the capacity model of attention (Kahneman, 1973), the working memory model (Baddeley, 2017), and the cognitive load theory (Sweller et al., 2011) suggested cognitive capacity or cognitive resource is limited for individuals' cognitive activities. Sweller et al. (2011, p. 43-44) suggested that working memory capacity is "extremely limited when processing novel information". Kahneman (1973) explained that an individual would use all available capacity to complete a given task. Nevertheless, the allocation of capacity is not determined by the individual's intention but by two sets of factors. One set of factors reflects the complexity of the task, and another set of factors is related to the individual's current

situation, including his mental wellbeing. For example, “what is happening to the subject, and the stress to which he is exposed” (Kahneman, 1973, p. 17). In the context of the present study, when children are completing the same SWM task, children with a higher level of internalising symptoms may be prone to feeling stressed due to hypervigilance, and children with higher levels of externalising symptoms may be less able to pay attention to the tasks. Both could lead to poor performance on the SWM task due to less cognitive capacity being allocated to the task.

In summary, whether there is a link between children’s developmental trajectories of internalising / externalising behaviours and their later SWM remained unclear. Therefore, the present study aims to fill in the gap. Furthermore, if a link is found, the present study intends to explore the implications of the link for practice in the fields of education and educational psychology. Firstly, academic performance is the most commonly used measure for learning outcomes (York et al., 2019). Given that child psychopathology symptoms correlate with academic performance (Sijtsema et al., 2014; Suldo et al., 2011), and SWM could predict academic performance (e.g., Aronen et al., 2005; Soltanlou et al., 2019), this study would check whether SWM explains the impact of child psychopathology development on children’s academic performance. Secondly, Bronfenbrenner’s bioecological theory of human development (Bronfenbrenner, 2005) depicts that individuals’ development involves interaction between individual characteristics and their environments such as home, school, neighbourhood, and social value. The bioecological theory of human development is highly endorsed by educational

psychology professionals[1], who work with children and their surrounding environments (Woolfson et al., 2003). Given the author's background (i.e., Trainee Educational Psychologist), this study would survey educational psychology professionals regarding the implications of the child psychopathology-SWM link for their practice.

The main research question of the present study is: *What is the relationship between the development of child psychopathology symptoms, i.e., trajectories of internalising problems, conduct problems, and hyperactivity / inattention, and later SWM performance*? Once a relationship is identified, two extended research questions will then be explored to deepen the understanding of the leading research question within the context of educational psychology, including:

1. *Does SWM mediate the impact of the development of child psychopathology symptoms on academic performance?*
2. *What are the implications of the relationship between the development of child psychopathology symptoms and SWM for educational psychology practice?*

[1] Educational psychology professionals (including Educational Psychologists, Trainee Educational Psychologists, Child and Adolescent Psychologists and Assistant Educational Psychologists) support children with special educational needs and disabilities (SEND) and their families.

Chapter 2

Theoretical Frameworks and Key Concepts

This chapter aims to, based on relevant theoretical models / frameworks, describe two key concepts of this study, i.e., spatial working memory (SWM) and child psychopathology.

2.1 What is spatial working memory?

The conceptualisation of SWM in this study is based on the description of working memory and spatial ability, which also include / lead to explanation around executive functions and academic performance.

2.1.1 Working memory models and spatial working memory

Working memory is in general recognised as the cognitive ability / function / process to hold and manipulate information including novel information by most working memory theoretical models, including, for example, the multicomponent model (Baddeley & Hitch, 1974; Baddeley, 2010; 2021) and the embedded-processes model (Cowan, 1999; 2010). The framework of executive functions (Diamond, 2013), which is not a specific model of working memory, also agrees with such a general definition of working memory. However, the theorists reported some disagreements regarding, for example, whether or not working memory is a cognitive entity, its structure and the extent of its domain-generality.

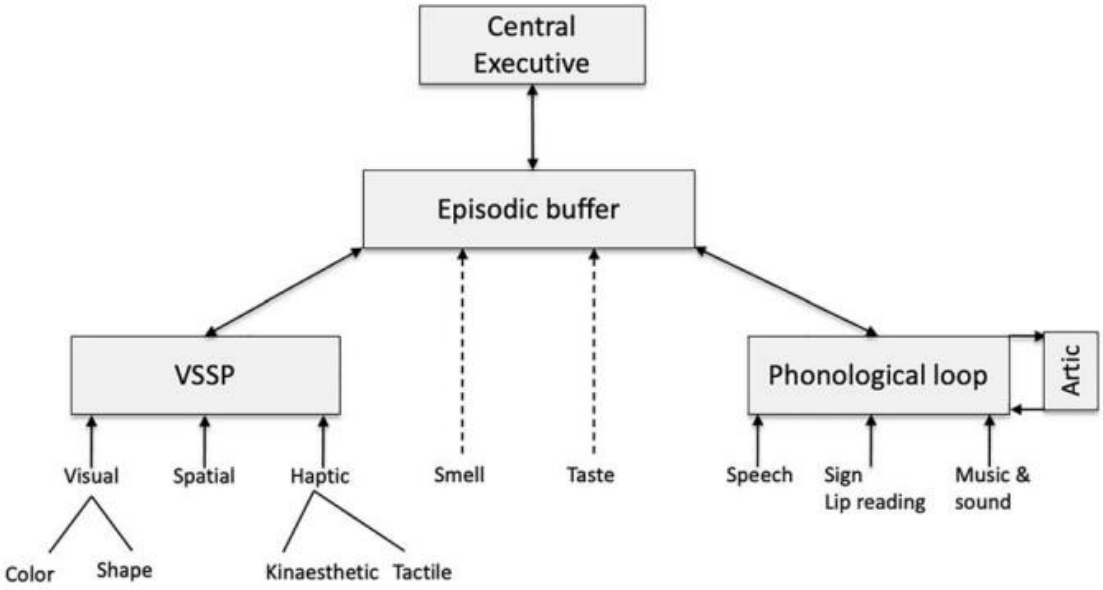
The multicomponent model**:** Baddeley and his colleagues (e.g., Baddeley & Hitch, 1974; Baddeley & Logie, 1999; Baddeley, 2010; 2021) proposed a multicomponent working memory model which describes working memory (WM) as the system or systems that are needed to hold things in mind when performing complex tasks such as reasoning, comprehension, and learning. According to Baddeley and Hitch's (1974) original model, working memory comprises a central executive - an overall attentional control system as well as supplementary storage systems - a phonological loop and a visuospatial sketchpad that stores and retains, respectively, auditory / verbal information and visual / spatial information while the central executive processing it. A series of early experiments (e.g., Baddeley & Lieberman, 1980 cited in Baddeley, 2017) found that verbal reasoning tasks and visual / spatial tasks remain unaffected by each other, suggesting that the visuospatial sketchpad and the phonological loop are separate and independent systems. But the direct evidence is sparse for the mechanism of the central executive although it plays a vital supervisory role regarding the control and regulation of information in working memory, leading to a common critic for the multicomponent model, i.e., the hypothetical central executive acts like a powerful mysterious “homunculus” or a convenient theoretical “ragbag” that is used to explain all functions that could not be attributed to the visuospatial sketchpad and the phonological loop while the relevant mechanisms remain unclear, for example, the enhancement of working memory via familiarity, the integration of different types of information, the storing of the information that is neither auditory / verbal nor visual / spatial such as smell and taste.

As a response, the model has been revised at least three times. Firstly, Baddeley and Logie (1999) clarified that the central executive purely processes information without

a supplementary storage function, and additional storage demands are met by accessing long-term memory or other subsystems; Then, a new component, i.e., the episodic buffer, was added to the model (Baddeley, 2000), which is postulated as a temporary storage system capable of integrating different types of information from perception, the visuospatial sketchpad, the phonological loop, and long-term memory. According to this modified model, the episodic buffer is, similar to the other two storage systems (i.e., the phonological loop and the visuospatial sketchpad), under the supervision of the central executive. Finally, with further analysis around the attentional functions of the central executive, the current multicomponent model (Figure 1) suggests the phonological loop / the visuospatial sketchpad not only maintains information but also acts like lower-level buffers combining information within the subsystem; the episodic buffer not only binds information from various sources (possibly including smell and taste) to integrated information chunks, but also provides conscious and the central executive with access to these information chunks (Baddeley et al., 2011; Baddeley, 2021). Episodic buffer tends to be “at the heart of the current model” (Baddeley et al., 2011, p1399).

Figure 1

The current multicomponent model illustrating the flow of information from perception to the episodic buffer



Note. *From Developing the Concept of Working Memory: The Role of Neuropsychology by Baddeley (2021).*

The embedded-processes model**:** Cowan's (1999, 2010) definition of working memory is recognised as the embedded-processes model, which attempts to suggest a relatively general way (compared to the multicomponent model) of working memory functioning regardless of the type of information**.** Cowan (1999, p62) defined working memory, at a functional level, as "cognitive processes that retain information in an unusually accessible state, suitable for carrying out any task with a mental component". According to the embedded-processes model, the cognitive processes of working memory, controlled by the

central executive, include, for example, activating relevant long-term memory, directing the focus of attention, and any other central executive processes that keep things temporarily in mind for completing cognitive tasks (Cowan, 2010). Cowan (2010) suggested the amount of activated memory (including long-term memory) could be unlimited while the focus of attention [also "awareness" according to Cowan (1999)] can only maintain a limited number of items; it is the focus of attention where information is maintained and / or combined to form new information.

Cowan (1999) emphasized that working memory is, rather than a theoretical entity that is arbitrarily labelled, any cognitive process that is needed to make the information accessible for completing complex cognitive tasks.

Working memory within the framework of executive functions**:** Executive functions is an umbrella term which refers to top-down mental processes that are required to make appropriate responses in novel situations, and to pay and maintain attention that is essential in completing any complex cognitive task; core executive functions include inhibition, working memory, and cognitive flexibility, based on which higher-order executive functions, e.g., reasoning, problem solving, planning, are built (Diamond, 2013). Chan et al. (2008) indicated that executive functions also include the mental processes that involve emotions, "belief" or "desires" such as regulating social behaviours and emotional responses. Executive function activities seem to be controlled by the prefrontal cortex (Diamond, 2013; Chan et al., 2008)

Within the framework of executive functions, working memory, as one of the core executive functions, refers to capabilities to hold and work with, in mind, information that

is no longer perceptually present; it appears to be independent from but closely linked with the other two core executive functions. For example, working memory and inhibition (i.e., capabilities to control attention, thoughts, behaviours, and emotions against instinct or external lure in order to form more appropriate responses) always co-occur, resulting in inconclusive debates around whether working memory incorporates inhibitory control / whether both operate on the same mechanism; cognitive flexibility (i.e., capabilities to think creatively and adopt other perspectives) is considered to develop based on working memory and inhibition (Diamond, 2013).

The definition of working memory / spatial working memory in the present study: Regarding the definition of working memory, the multicomponent model, the embedded-processes model, and the framework of executive functions show some commonalities as well as differences, which helped to inform the definition of working memory / spatial working memory in the present study:

1) working memory involves active processing of information, which is beyond the function of short-term memory (Jarrold & Towse, 2006). This active processing of information, however, was captured differently in the three previously mentioned models / framework. The multicomponent model attributes the active processing of information to the buffer function of phonological loop / visuospatial sketchpad, the episodic buffer (where information is combined to form new chunks), and the central executive (where attention is controlled); the embedded-processes model describes this active processing of information as, for example, activating relevant long-term memory and navigating the focus of attention. Both models consider the

effortful control of attention[2] as a working memory function delivered by the central executive, whereas the framework of executive functions does not. The framework of executive functions views the effortful control of attention as part of inhibition (e.g., selective attention, cognitive inhibition), which is by itself a core executive function. The framework of executive functions tends to limit the active processing of information in working memory to holding and working with information in memory for longer time that a cognitive task would require; however, this framework did not deny that inhibition plays an essential role in the working memory process (as a matter of fact, this framework suggests that working memory and inhibition co-occur). Therefore, regardless of whether the model or the framework views the effortful control of attention as part of working memory or not, working memory tasks need the effortful control of attention, and it is this effortful control of attention (as well as other related executive controlled processes if any) differentiated the working memory from short-term memory.

In general, working memory in the multicomponent model and the embedded-processes model includes an element of central executive, hence appearing equivalent to the combination of three core executive functions (i.e., working memory, inhibition, cognitive flexibility). Indeed, McCabe et al. (2010) reported a very high correlation (r = .97) between the central executive and executive functions constructs. Therefore, this study will, sometimes, refer to the

[2] The effortful control of attention, also called attentional control as a function of the central executive in the multicomponent model (Baddeley, 2021) or the focus of attention as a central executive process in the embedded-processes model (Cowan, 2010).

central executive using broader terms including executive functioning skills or executive functions in the remainder of the thesis.

2) Working memory plays an essential role in individuals' responding appropriately to novel situation, which involves learning, i.e., encoding / interpreting / creating new information as well as registering new information onto long-term memory. The multicomponent model and the embedded-processes model both explained how working memory support learning from a perspective of information processing. The former assumed new pieces of information, while being maintained and combined in phonological loop or visuo-spatial sketchpad, are further integrated into chunks (or "episodes" as Baddeley et al., 2011 described) and interacting with relevant long-term memory in episodic buffer, under the supervision of the consciousness and the central executive. The embedded-processes model suggests pieces of information held in the focus of attention can be combined to form chunks, i.e., new and larger units; some of the chunks can then be refreshed using attention to enter long-term memory as newly learned items (Cowan, 2010). On a more general level (in comparison to the specific perspective of information processing), the framework of executive functions suggests working memory, inhibition, and cognitive flexibility, as core executive functions, are building blocks for higher-order executive functions such as reasoning, problem solving and planning, which are essential for learning something new.
3) Working memory works via domain-general systems and domain-specific systems. In the latest multicomponent model (Baddeley, 2021), working memory comprises two domain-general systems mainly for effortful control of attention and

information processing, i.e., the central executive and the episodic buffer, and two domain-specific systems mainly for the storage and maintenance of either auditory / verbal information or visual / spatial information, i.e., the phonological loop and visuospatial sketchpad. The embedded-processes model (Cowan, 1999; 2010), however, tends to suggest the storage and maintenance of different types of information may in fact work following the same principles; therefore, the embedded-processes model emphasized the domain-general nature of working memory in terms of, for example, the effortful control of attention that leads to the awareness of the activated long-term memory and the focus of attention.

The current study would adopt the view of the multicomponent model regarding the domain-generality of working memory. Baddeley and his colleagues (e.g., Baddeley & Hitch, 1974; Baddeley & Logie, 1999; Baddeley, 2010; Baddeley, 2021) proposed separated verbal and visuospatial components in the multicomponent model, based on research data that showed a visual tracking task disrupted the visuospatial but not the verbal short-term memory task, indicating separate processing systems for visuospatial and verbal information. Additionally, later empirical research tends to support the multicomponent model in terms of the domain-generality of working memory (please see Jarrold & Towse, 2006 for a review); some studies (Alloway et al., 2006; Gathercole et al., 2004) supported the notion and the structure of working memory proposed by the multicomponent model using data from children as young as 4 years old. In the meantime, it appears relatively more difficult to identify the same principles underlying the processing /

maintenance of different types of information, if any, as suggested by Cowan (1999; 2010).

In summary, the present study would consider working memory as the cognitive processes that hold information (e.g., information storage and maintenance), and work with information (e.g., information coding and combination) using some of the executive functions (e.g., effortful control of attention) during complex cognitive activities including learning and responding to novel situations. The current study would adopt the view of the multicomponent model regarding the domain-generality of working memory. In other words, this study considers that working memory can be categorised into verbal working memory and visual / spatial working memory, operating via a general attentional control system and / or domain-general processing systems, but separate storage / maintenance systems for, respectively, verbal and visuospatial information.

The current study is a secondary analysis study and the only measure for working memory available is a version of the Spatial Stroop task i.e., the Cambridge Neuropsychological Test Automated Battery, which is used to assess spatial working memory (SWM) with a focus on inhibitory control (including effortful control of attention) (Diamond, 2013). Given that, as previously mentioned, there is limited research into the relationship between child psychopathology and SWM, this study chose to explore SWM in specific. In line with the definition for working memory, the present study considers SWM as a specific type of working memory involving the holding and working with visual / spatial information using some of the executive functions during complex cognitive activities. In the context of the multicomponent model, SWM could involve the visuospatial sketchpad, the episodic buffer, and the central executive.

2.1.2 Spatial ability and spatial working memory

Spatial ability is in general recognized as a multifaceted construct and an important independent component of human intelligence (Lohman, 1993; Yılmaz, 2009; Buckley et al., 2018). Lohman's (1993, p.3) definition of spatial ability, i.e., the ability to generate, retain, retrieve, and transform well-structured visual images, is usually referred to in empirical studies of spatial ability (e.g., Wai et al., 2009; Meneghetti et al., 2009). However, there is so far no universally accepted definition of spatial ability in terms of a complete list of included factors, partly due to the inconsistent naming of factors and a growing list of newly discovered factors (Yılmaz, 2009; Buckley et al., 2018). Nevertheless, some factors have been consistently considered as essential factors of spatial ability (Lohman, 1993; Yılmaz, 2009; Buckley et al., 2018), for example:

spatial visualization / visualization: the ability to perceive complex patterns and mentally manipulate (e.g., rotate, twist, or invert) them without reference to self., which requires considerable reasoning skill.

spatial orientation: the ability to imagine the appearance of an object from different perspectives. Some researchers (e.g., Lohman, 1993) views spatial orientation as inseparable from visualization.

speeded rotation / spatial relations: the ability to quickly manipulate relatively simple visual patterns, by whatever means.

closure speed: the ability to quickly identify a known visual pattern when it is disguised or obscured without knowing in advance what the pattern in.

closure flexibility: the ability to identify a visual pattern when it is disguised or obscured, knowing in advance what the pattern in.

perceptual speed: the ability to quickly find a unique item in a group of identical items, a specific visual pattern in a visual field, or accurately match one of more patterns.

visual memory: the ability to remember complex patterns for short time.

Additionally, Yılmaz (2009) suggested that *dynamic spatial ability* (i.e., spatial ability dealing with a moving stimulus) and *environmental ability* (i.e., spatial ability regarding navigating in one's surroundings) have gained increasingly more attention recently, introducing the three-dimension perspective into the exploration of spatial ability.

SWM is the working memory of visual / spatial information, hence the process of completing a SWM task inevitably involves utilising some factors of spatial ability. The nature / content of the SWM task would decide which spatial ability factor(s) are involved in such a process. For example, the Cambridge Neuropsychological Test Automated Battery used by this study is likely to involve, at least, visual memory and perceptual speed.

2.1.3 Spatial working memory and academic performance

SWM as part of the working memory is associated with children's academic performance. Working memory measures are reported to account for about 50% to 70% of the variance in measures of higher-level cognitive skills such as reasoning, problem solving and planning, possibly reflecting domain-general underpinnings (Jarrold & Towse, 2006). The domain-general underpinnings refer to, in the context of the current study, a general attentional control system and / or domain-general processing systems. SWM is of interest in this study, partly due to the limitation of secondary analysis research. But, as a specific type of working memory, SWM would reflect the domain-general underpinnings of working memory anyway.

The SWM measure available in the present study, i.e., the Cambridge Neuropsychological Test Automated Battery, is reported to have a focus on the assessment of inhibitory control, which is an important domain-general feature of working memory (Diamond, 2013). Hence, SWM could as well account for at least some variance in measures of higher-level cognitive skills including learning in a school environment. Indeed, impaired SWM has been related to several higher-level cognitive outcomes in children including academic performance, i.e., children's performance in a school context on "academic achievement, the accomplishment of learning objectives, and acquisition of skills and competencies" (York et al., 2019, p. 7), which can also be predicted by one's executive functions (Clair-Thompson & Gathercole, 2006; Clark et al, 2002). For example, Aronen et al. (2005) reported, based on data from 66 schoolchildren aged 6 to 13 years, that high number of errors in the SWM task, suggesting poorer SWM, correlated with poorer teacher-reported attention and lower teacher-reported academic performance. Fanari et al., (2019) assessed 43 children's numerical skills at a mean age of 78 months and their math problem solving skills at two later timepoints (mean ages of 83 and 93 months), as well as these children's visual and spatial working memory at all three timepoints; they reported SWM explained, at the first timepoint, 21% of the variance of the numerical skills which in turn predicted participants' mathematic achievement at the second timepoint with 25% of the variance explained; at the third timepoint, visual and spatial working memory explained 25% of the variance in participants' mathematics achievement.

A correlation between spatial ability and academic performance has been established in many empirical studies, especially in science, technology, engineering and

mathematics (STEM (please see reviews of Harle & Towns, 2011; Buckley et al., 2018). Harle and Towns (2011), using examples from chemistry, explained that the teaching and learning of chemistry often involve using spatial ability to understand representations of molecules, reactions, and theories; they also indicated that students with high spatial ability tend to adopt different problem-solving approach from these with low spatial ability in chemistry and other STEM learning activities. Wai, et al. (2009) followed 400,000 students from U.S high schools for 11+ years and found that good spatial ability emerged as a salient psychological attribute in participants who grew up to achieve or have achieved advanced educational credentials in STEM (bachelor's, master's, or PhD). In the meantime, Wai, et al.'s (2009) study also revealed spatial ability plays relatively less important role in humanities and social science in comparison to verbal ability / mathematical ability.

Given that spatial ability seems to predict academic performance especially in STEM, SWM could play a unique role in children's academic outcomes because it utilises spatial ability to work with visual / spatial information within the working memory system. Findings from empirical studies tend to support the correlation between SWM and academic performance across subjects. However, it is too early to summarise that SWM correlates more strongly to certain subjects than others as relevant research in some subjects, e.g., science and literacy, appears relatively insufficient to draw a general conclusion. Allen et al. (2019) conducted a systematic review of 35 articles and found an overall significant positive relationship between visuospatial working memory and maths performance including numerical operations and mathematical reasoning. Yuan et al. (2006) indicated mix findings were found in studies regarding the relationship between working memory and science achievement, although a positive relationship is more

commonly reported; they suggested more research is needed to explore the roles of different components of working memory (i.e., phonological and visuospatial working memory) in science learning. Yet, SWM and science learning remains a relatively under-researched area. In terms of literacy attainment, although verbal working memory seems to be a more consistent predictor than SWM (Clair-Thompson & Gathercole, 2006), SWM still accounts for some unique variance in children's literacy ability, especially children's early / emergent writing skills. Bourke et al. (2014), based in data gathered from 143 children from reception year, found that visuo-spatial working memory continues to be a significant predictor for early writing skills, i.e., single word spelling; narrative text writing, even after controlling effects of age, nonverbal cognitive ability, single-word reading, phonological working memory, the ability to accurately copy shape onto paper and the ability to write upper and lower case letters from dictation. Fischbach et al. (2014) reported that, comparing to typically developing children, children with literacy disorders, e.g., reading and / or spelling impairments, showed difficulties with SWM in terms of storing and manipulating dynamic visual / spatial information. However, this finding lacks generalizability as their sample size is relatively small – 28 children from primary schools with literacy disorder and 28 children without learning difficulties as the control group.

2.2 What is child psychopathology

Child psychopathology has, in general, been conceptualised as children's adaptational difficulty or areas of needs caused by atypical mental health development, e.g., a pause, a regression, a deviation in development (Mash & Dozois, 2003). Child psychopathology is an umbrella term covering a wide range of social and emotional difficulties; it could be manifested by social emotional and / or mental health needs

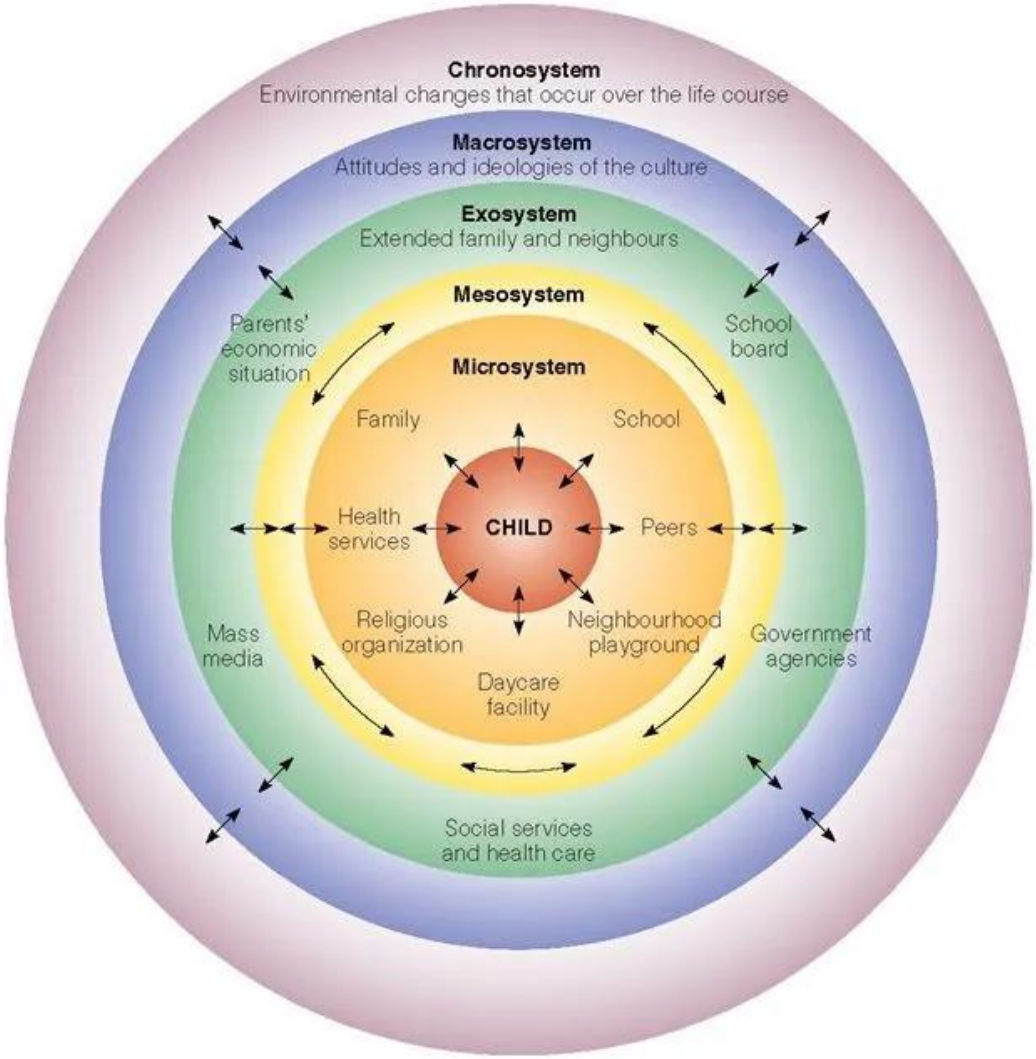
(including behaviour). Examples of such difficulties / needs include becoming withdrawn or isolated, displaying challenging, disruptive or disturbing behaviours, and mental health disorders such as attention deficit disorder, attention deficit hyperactive disorder, or attachment disorder (Carroll & Hurry, 2018). Based on clustered observable behaviours, psychology researchers tended to adopt dimensional approaches (Mash & Dozois, 2003) or bottom-up paradigms (Achenbach, 2020) which commonly group psychopathology into internalising problems / emotional problems, and externalising problems / behavioural problems. Such approaches typically view behaviours as lying on a continuum from the age-appropriate norm to severe concern according to the intensity, frequency, and duration of the behaviours. The present study focuses on child internalising (emotional) and externalising (behavioural) problems which may be defined as follows: Internalising problems are one type of child psychopathology that is based on overcontrolled symptoms such as anxiety, depression, social withdrawal, and somatic complaints without apparent medical reasons. Externalising problems are one type of child psychopathology that is based on under-controlled symptoms such as hyperactivity, conduct problems, and antisocial behaviours.

The bioecological theory of human development (Bronfenbrenner, 2005) provided the present study with a framework for the conceptualisation of how psychopathology – specifically emotional and behavioural problems - develops across childhood and adolescence. However, it should be noted that it is not a theory that can be applied to the design of the aims or methods per se. Still, it can aid in our understanding of child development broadly. It considers human development across several outcomes including behaviour, emotion, ability, motivation, knowledge and skills, and suggests they are the

product of proximal processes where an individual interacts with their surrounding environment such as parent-child interaction, child-child play, and learning new skills (Bronfenbrenner, 2005). Bronfenbrenner (2005) explains that proximal processes are affected by factors including characteristics of the developing person, the environment, the nature of development outcomes, and time. Hence, the bioecological theory of human development proposed a Process-Person-Context-Time (PPCT) model for studies of human development where the Process stands for proximal processes, Person refers to individual characteristics that a person brings to any proximal process, Context means the four interconnected systems (i.e., the microsystem, the mesosystem, the exosystem, and the macrosystem), and Time considers the changes over time individuals may go through as well as the environment (i.e., the chronosystem) (Tudge et al., 2009). Figure 2 depicts the bioecological theory in terms of the PPCT model in the context of child development. The microsystem presents the immediate environment that is in direct contact with the child such as parents and school peers. The mesosystem means the interactions between the child's microsystems, e.g., home-school communication; the exosystem includes the social structures that could indirectly influence children's outcomes such as neighbourhoods and the media; the macrosystem refers to the cultural context, and the chronosystem captures the environmental changes that the child may experience over the life course

Figure 2

Bronfenbrenner's Bioecological Theory



Note. From *Bronfenbrenner's Ecological Systems Theory* by O. Guy-Evans, 2020, (https://www.simplypsychology.org/Bronfenbrenner.html)

Child emotional and behavioural problems interact with their causes and outcomes in a dynamic way, reflecting the bioecological theory (Capaldi et al., 2012; Fanti, 2010; Mash & Dozois, 2003). It is increasingly recognised that the longitudinal trajectory of child behaviour and emotional symptoms for a given child, like that of other child outcomes,

depends on within-child characteristics (e.g., age, gender, temperament), the outside-child environment (e.g., family income, parental mental health, social judgment), and complex interactions between the two over the course of child development (Mash & Dozois, 2003). In the meantime, child emotional and behavioural difficulties have been associated with a range of negative outcomes including poor academic performance (Ende et al., 2016; Suldo et al., 2011), impaired language skills (Bornstein et al., 2013), impaired cognitive functioning in attention, executive functioning, or memory (Blanken et al., 2017), and poor social competence (Sijtsema et al., 2014).

In the present study, the link between child emotional and behavioural problems and SWM is the focus of exploration, and children's SWM and academic performance are two outcomes of interest. Recognising the complex interaction between child characteristics (e.g., psychopathology, age, gender, and verbal ability), child outcomes (e.g., SWM, academic performance), and the proximal and distal context (e.g., family poverty, maternal education, ethnicity, and maternal depression), this study considered how child development occurs within the chronosystem by incorporating a longitudinal element to the study where children's psychopathology was measured at four different ages (SWM and academic performance were only measured at a one-time point as limited by the secondary analysis). Once a link between SWM and child psychopathology can be identified, given that SWM also tends to predict children's academic performance, the present study would check whether SWM explains the impact of child psychopathology development on children's academic performance.

Chapter 3

Literature Review

3.1 Trajectories of Internalising Problems

Some longitudinal studies, with a large sample size which followed children from the age of 2, 3, or 4 years to the age of 11 or 12 years (e.g., Fanti, 2010; Parkes et al., 2016; Sterba et al., 2007), summarised that there seemed to be at least three groups in trajectories of internalising problems: the majority of children consistently presented low levels or moderate levels of internalising problems while some showed chronically high levels of internalising symptoms. Korhonen et al. (2018) studied participants' problem behaviours during the age of 4 or 5 to 26 or 27 years and found three groups, i.e., low/decreasing, increasing, and high; however, it was unclear whether their sample represented the target population as it was relatively small and biased – the original sample was 350 children followed from age 6 months while the final sample consisted of 114 26-27 years old adults who returned the follow-up questionnaire. Nivard et al. (2017) followed children from the age of 7 years to the age of 15 years and reported five groups for participants' internalising problems: the very low-level group (22.7%), the low-level group (41.8%), one group with decreasing internalising problems (5.1%), one group of children whose internalising problems increased steadily over the years since childhood (17.8%) and the fifth group showing a low level of internalising symptoms until age 13 and a sharp increase was observed at age 15. It is important to note that Nivard et al. (2017) explored the trajectories for internalising problems using mother-report data at children's ages of 7, 10, and 13

years, but self-report data at 15 years. The discrepancy between child-report and parent-report data (Hope et al., 1999) may have an impact on the accuracy of emerged trajectories in Nivard et al.'s (2017) analysis. In comparison, Flouri et al. (2018) assessed 16,844 children's internalising problems measured by the parent-report Strengths and Difficulties Questionnaire four times from age 3 to age 11 and reported four groups in both boys and girls: typically developing group (81% of males, 84% of females), improvers (6% of males, 7% of females), deteriorators (7% of males, 5% of females) and troubled (6% of males, 4% of females).

It was reported that, between ages 2 to 11, the trajectories in the low-level group remained relatively stable, but different developmental trends were found in groups with a moderate or high level of internalising problems. For instance, Fanti (2010) reported the trajectories in the high-level group tended to increase in general and that the moderate-level group remained stable. While Sterba et al. (2007) found the high-level group showed a consistent level of internalising problems, but children's moderate levels of internalising problems showed a decreasing-then-increasing pattern. Both studies retrieved their data from the American National Institute of Child Health and Development Study. Flouri et al. (2018), based on the data from the UK Millennium Cohort Study, analysed in the present study, reported increasing internalising problems in the high-risk groups, and two moderate risk groups showing respectively increasing and decreasing trends of problem behaviours. However, Flouri et al. (2018) investigated the trajectories in girls and boys separately. Therefore, trajectories of internalising problems could be divided into at least three groups, but the developmental trend of each trajectory remains unclear, especially in a UK general population.

3.2 Internalising Problems and SWM

The evidence for a link between internalising problems and SWM in clinical groups or adults appeared to be more consistent. For example, anxiety and depression seem to have an impact on SWM, and their impact seems to vary by their severity. For instance, Christopher and MacDonald (2005) reported impairments in all components of working memory of 35 patients with clinical depression. In another study, anxiety caused by the 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 significantly affect SWM in Lukasik et al.'s (2019) non-clinical sample of 503 adults. There is limited research around the link between internalising problems and SWM in a child population. Most of these studies (Blanken et al., 2017; Greenwald & Carr, 2018; Halahakoon et al., 2019) have focused on the impact of children's internalising behaviours on the general working memory or cognitive ability rather than the specific SWM. Additionally, these studies tended to measure children's internalising behaviours at one timepoint which failed to reflect the dynamic nature of child psychopathology.

3.3 Trajectories of Externalising Problems

Some researchers (e.g., Flouri et al., 2018; Korhonen et al., 2018; Olson et al., 2017) reported that there were four groups in the trajectories of externalising problems from childhood to adolescence, while some other studies (e.g., Fanti, 2010; Nivard et al., 2017) found five groups. Nevertheless, it seemed to some extent agreed across studies that there were one group of children exhibiting a persistently high level of externalising problems, and one group of consistently low-level externalising symptoms from childhood to early adolescence (Fanti, 2010; Korhonen et al., 2018; Nivard et al., 2017; Olson et al., 2017).

Franke et al. (2018) reviewed studies of Attention Deficit Hyperactivity Disorder (ADHD) trajectories across the lifespan and proposed a theoretical five group model for the developmental trajectories of ADHD from age 4 to 40; there was one persistent ADHD group, one typically developing group with a low level of ADHD symptoms, one remitting group, one childhood-unrecognised group which showed ADHD onset in adulthood, and one group with secondary ADHD (e.g., ADHD acquired due to traumatic brain injuries) which showed a similar trajectory path as the childhood-unrecognised group until the triggering event. Gutman et al. (2019) reported four trajectory groups of conduct problem measured by Strengths and Difficulties Questionnaire in 17,206 children followed from age 3 to age 14, namely, adolescent-onset group (12.7%), low group (56.4%), childhood-limited group (23.2%) and persistent group (7.7%). Olson et al. (2017) also found four groups after analysing 238 children's externalising behaviours such as physical aggression, destructive behaviour and hyperactivity / inattention measured by Child Behaviour Checklist: The chronic group (3.8%), the rising group (9.7%), the decreasing group (16%) and the low group (70.6%), while Fanti (2010) found five groups and 24.7% of the children in his sample (N = 1232) presented low levels of externalising problems measured by Child Behaviour Checklist between age 2 and age 12; the other four groups were chronic (8.4%), high desister (18%), moderate (10.7%), and moderate desister (38.2%). As described, these studies of externalising behaviour trajectories focused on either a specific externalising problem, e.g., hyperactivity/inattention, conduct problem, or externalising behaviours in general. However, hyperactivity/inattention and conduct problems were associated with SWM differently (more details see Section 3.4 in this chapter). Therefore,

this study investigated the trajectories for hyperactivity/inattention and conduct problems separately using data from the same sample.

3.4 Externalising Problems and SWM

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. However, there is significant specificity by type, with ADHD being more consistent and more strongly associated with impaired working memory in general. For example, two meta-analyses (Schoemaker et al., 2013; Willcutt et al., 2005) reported small to large effect sizes of impaired executive functioning in children with ADHD. Some researchers (e.g., Martinussen et al., 2005; Ferrin & Vance, 2012; Lui & Tannock, 2007) reported relationships between ADHD and working memory deficits, particularly in the visuospatial domain. However, most of these studies (e.g., (Barnett et al., 2001; Cairney, 2002; Tripp et al., 2002) tested the concurrent ADHD-SWM association by comparing the SWM skills of a relatively small sample of children referred to clinics to that of the control group. (Brocki et al., 2007) investigated the association concurrently and longitudinally using data from a clinical sample, however, found null ADHD-SWM associations. Therefore, there is a lack of understanding in, firstly, whether ADHD symptoms link with SWM performance in a general population and, secondly, whether such associations are longitudinal.

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. They 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 pre-schoolers 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 than the control group, even after controlling for ADHD comorbidity. More recently, Griffith et al. (2019) found that difficulties in working memory and sustained attention were related to negative affect symptoms of ODD, but not to oppositional and antagonistic behaviour. Besides the contradictory findings, most of these studies measured symptoms of ODD or CD at a single time point, without taking into consideration the developmental nature of child psychopathology.

3.5 Child Psychopathology and Academic Performance

Symptoms of child psychopathology correlate with children's academic performance concurrently and longitudinally (Sijtsema et al., 2014; Suldo et al., 2011). Elevated levels of internalising symptoms have been associated with poor academic performance. Pedersen et al. (2019) reported that teacher-rated overall academic achievement in Norwegian, English, mathematics, and social studies was negatively associated with self-reported symptoms of depression and teacher-reported internalising symptoms in 750 children aged 8-12 years. Wickersham et al. (2021) conducted a systematic review and meta-analysis that focused on the longitudinal association between depression and subsequent academic performance. They reported a small but significant negative correlation (r=-0.19). However, such associations are not consistently significant in longitudinal studies (Patalay & Emla, 2016). For instance, Ende et al. (2016) assessed 816 children four times between the ages of 6-10 years and the ages of 14-18 years and, using

cross-lagged models, reported that internalising problems at earlier ages measured by parent-rated Child Behaviour Checklist (CBCL) did not predict later academic performance measured as the sum of the graded subjects by Teacher Report Form (TRF). The same result was found for earlier teacher-reported internalising problems measured by TRF and later parent-reported academic performance, i.e., a combination of the graded subjects and some additional items from the CBCL.

The negative association between externalising behaviours and academic outcomes, compared with that between internalising behaviours and academic outcomes, appears more consistent in not only cross-sectional but also longitudinal studies. For example, Ende et al. (2016) indicated that earlier parent-rated and teacher-reported externalising behaviours predict later academic performance measured by TRF and CBCL, respectively. Clark et al. (2002), analysing data from 110 adolescents, discovered that children with ADHD and / or Oppositional Defiant Disorder/Conduct Disorder (ODD / CD) showed poorer word recognition ability or executive functioning skills. Some researchers (e.g., Arnold et al., 2020; Daley & Birchwood, 2010; Hinshaw, 1992) identified that hyperactivity or inattention behaviours seemed to show stronger correlations with academic performance compared to other types of externalising behaviours. Arnold et al. (2020) conducted a systematic review on the impact of ADHD on later academic outcomes including academic performance such as grades, high school completion etc.; it was reported that untreated ADHD correlates with adverse academic outcomes in long term.

There is, in general, little research focused on the association between internalising behaviours or externalising behaviours and specific subjects of academic performance, e.g., English, maths, and science. Most relevant research used a general or aggregated

measure for academic performance such as GPA (see Wickersham et al., 2021 for a systematic review and meta-analysis) or the sum of scores on different subjects (e.g., Ende et al., 2016; Pedersen et al., 2019). Nevertheless, a large body of research investigated the correlation between either domain or both domains of child psychopathology and literacy difficulties. Francis et al. (2019) conducted a systematic review and meta-analysis around the association between poor reading and internalising problems. They suggested that poor readers showed significantly higher levels of overall internalising problems (d=0.41), anxiety (d=0.41), and depression (d=0.23). Most of the research on literacy difficulties and child psychopathology used a small or selective sample. There was one study, i.e., Carroll et al. (2005), out of 34 studies included in Francis et al. (2019) that was conducted using data from a general child population in the UK. Carroll et al. (2005) collected data from 5,752 children aged 9 to 15 years and assessed the relationships between literacy difficulties, identified by the scales of single word reading and spelling of the British Ability Scales II, and different domains of child psychopathology, including ADHD, conduct/oppositional defiant disorder, depression, and anxiety disorder. The results revealed a significant association between literacy difficulties and externalising problems or anxiety disorder. The association tends to be stronger with the inattentive type of ADHD than with the hyperactive type of ADHD. Nevertheless, given the cross-sectional research design, Carroll et al. (2005) did not offer an analysis of children's behaviour over a period of time.

There is relatively scarce research on the concurrent or longitudinal association between child psychopathology and learning difficulties related to maths or science, although it is important for preventions and interventions of relevant specific learning

difficulties such as dyscalculia. Taanila et al. (2011), using teacher-reported data for 1774 children with an average age of 8 years, reported an association between maths difficulties and aggressiveness / hyperactivity in boys, as well as an association between maths difficulties and anxiety symptoms in girls. But, again, it was a cross-sectional study that assessed children's problem behaviour at one time-point.

In summary, the impact of child psychopathology symptoms on academic performance has been well established in research (Sijtsema et al., 2014; Suldo et al., 2011). Children's higher levels of psychopathology symptoms are associated with poorer academic performance in general but especially in the domain of ADHD (Arnold et al., 2020; Daley & Birchwood, 2010), which is in line with an understanding that ADHD is linked with impairments in executive functioning (Martinussen et al., 2005; Schoemaker et al., 2013; Willcutt et al., 2005). However, there has been little exploration into the links between psychopathology and academic achievement by subject. If the present study identifies a link between child psychopathology and SWM, SWM could then potentially plays a role in explaining the impact of child psychopathology symptoms on academic performance because it correlates with both.

3.6 Confounding Variables for Childhood Psychopathology and Adolescent SWM

Confounding variables correlate with both the independent variable and the outcome variable; confounding variables should be included as covariates in statistical analyses such as regression to rule out alternative mechanisms that explain the outcome of interest (Frank, 2000). In a systematic review, Blasiman and Was (2018) listed several factors that were consistently considered in the literature as influential for working memory or SWM performance specifically. These factors were intelligence, age, mental illness, and other

medical conditions, emotion, stress and anxiety, stereotype threat linked to gender, ethnicity, and socio-economic status (SES), sleep, bilingualism, drug use, and brain stimulation. Although gender differences of SWM seemed to disappear in studies with a small sample size (e.g., Postma et al., 2004), gender differences in performance of SWM were well documented that male participants seemed to outperform females in SWM tests (see a meta-analysis of Voyer et al., 2017). Additionally, maternal depression was found associated with decreased working memory capacity in children (Hughes et al., 2013). Meanwhile, intelligence, gender, maternal depression, and SES were also considered as significant predictors for the development of children's internalising and externalising behaviours (Cummings & Davies, 1994; Dekker et al., 2007; Flouri et al., 2018; Leve et al., 2005; Mesman et al., 2001). It was reported that children who showed lower intelligence scores, came from families with a higher level of maternal depression and lower SES were more likely to present higher levels of problem behaviours. In summary, intelligence, gender, maternal depression, and SES were considered as the confounding variables in the present study, and they were included as covariates in the regression data analysis.

Chapter 4

Childhood Trajectories of Internalising Problems, Conduct Problems and Hyperactivity / inattention and SWM in Adolescence

It appears that there might be 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. Therefore, it is unclear what the association is in the general child population, especially when a longitudinal lens is applied, which is vital given the temporal instability of child psychopathology symptoms in the general population. The present 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 the present study the role of different trajectory groups of internalising symptoms and externalising symptoms (conduct problems and hyperactivity / inattention in the present study) in later SWM performance. Given that the association between SWM and externalising symptoms differ by symptom domain, the present study modelled the SWM links with hyperactivity / inattention and conduct problems separately.

4.1 Methodology

4.1.1 Participants

The data in the present study 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 (Centre for Longitudinal Studies [CLS] | Millennium Cohort Study, n.d.). The recruited sample was clustered at the electoral ward level. It 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). In MCS, SWM was measured at Sweep 5, and symptoms of child psychopathology were collected via an interview with the primary carer since Sweep 2. Therefore, we used data from Sweeps 2 to 5 for the present 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, the present study included MCS children (singletons and first-born multiples) with data on symptoms on at least two sweeps. Analytic samples were singletons and first-born twins or triplets as the inclusion of siblings may potentially bias the estimates if children are not clustered into families in models. Figures 3 and 4 show the flow charts for all analyses.

Figure 3

Analytic Samples for GBTM

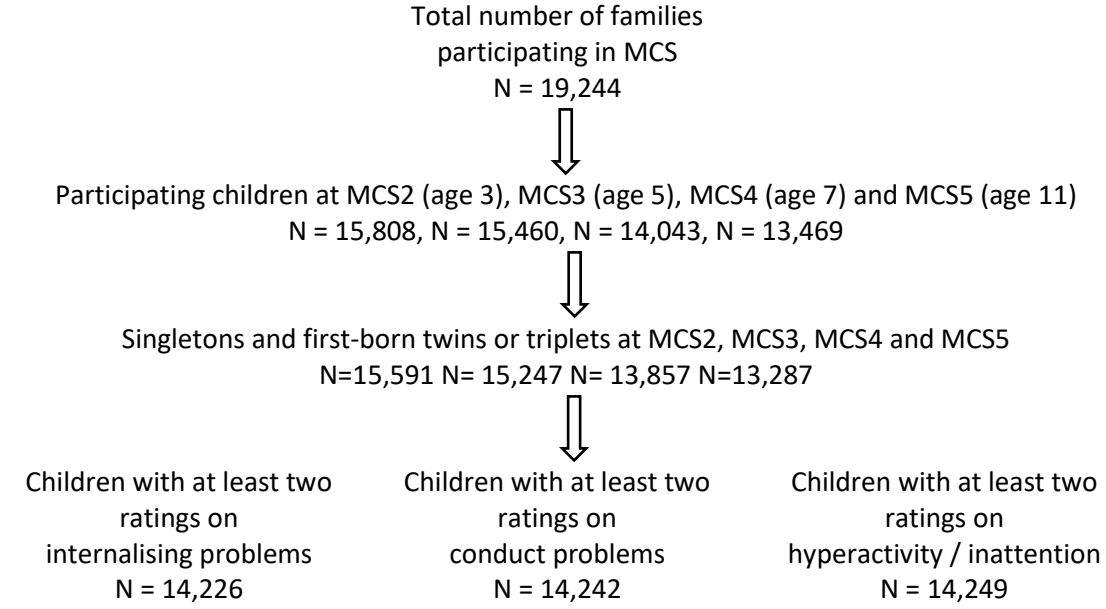
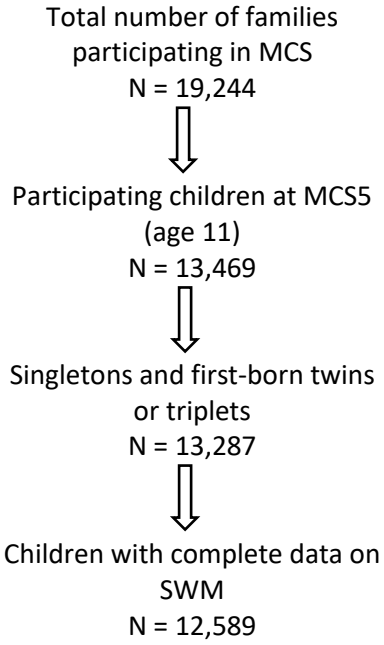


Figure 4

Analytic Sample for Multiple Regression Analyses



4.1.2 Measures

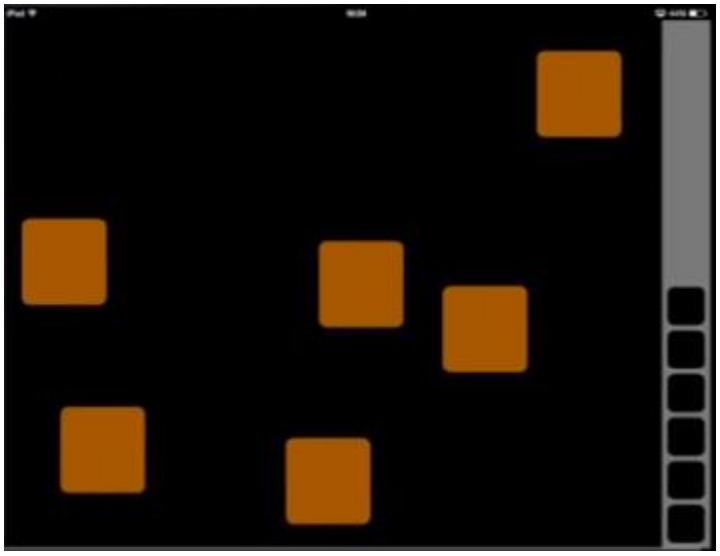
Spatial Working Memory

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 5). The difficulty level increases as the number of boxes increase from three to eight. Once a token is found in a box and placed in 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 that had already been found empty within one search (within errors) or revisit boxes that previously contained tokens within one trial (between errors). The colour and position of the boxes change from trial to trial to avoid the use of stereotyped search strategies. In MCS, participants had a chance to practise three trials with three boxes in each trial before the test. The test consisted of three blocks with four trials in each; the number of boxes increased from four to six to eight. 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. The 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 higher scores on strategy suggested poorer SWM performance. The measure of total errors tends to focus on skills in

memorizing the visual and spatial information, while the measure of strategy, in addition, measures some of the executive functions (e.g., planning skills) related to the operation of the visuospatial sketchpad.

Figure 5

An Example of The SWM Task on A Screen



Internalising Problems, Conduct Problems and Hyperactivity / inattention

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: 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 (Youthinmind, n.d.), the present study 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. The present study banded children's scores in all

areas to two levels (0 = normal; 1 = at risk) according to established cut-offs (Goodman, 1997). Children with scores below cut-off are considered 'normal' (80% in the general population), and those with scores above the 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 & Was, 2018; Cummings & Davies, 1994; Dekker et al., 2007; Hughes et al., 2013; Leve et al., 2005; Mesman et al., 2001; Voyer et al., 2017). ***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 the mean number of sweeps that the mother reported as having clinically meaningful depression (above the cut-off, i.e., score of 6). The present study approximated ***SES*** by family poverty, maternal education, and ethnicity. The Organisation for Economic Co-operation and Development (OECD) indicator was the measure for family poverty that the family was above or below the poverty line for MCS2 to MCS5. The present study 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 that described an individual's ethnicity as one of the 6 UK Census ethnic groups at MCS5.

4.1.3 Ethical Considerations

All the families eligible for the MCS study received consent letters and leaflets explaining the purpose and nature of the MCS from the Analytical Services Directorate (ASD) Information Centre before they decided on attending the project. 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. The present study obtained ethics approval from the Institute of Education, University College London.

4.1.4 Analytic Strategy

The present study adopted secondary analyses of quantitative data. 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). For GBTM, the present study used *Traj*, a free plugin in STATA. 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).

At the first stage of the data analysis, the researcher fitted children's SDQ banded scores from age 3 to age 11 to binary-distribution models using GBTM. 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 the present study is fitted up to a quadratic relationship because the data available were collected at four time points, and at least five are needed to fit a higher-order model (King et al., 2018). 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. Following a two-step model selection process suggested by Nagin (2005), the researcher firstly decided how many groups should be included in the models. As mentioned in Chapter 3 literature review, children's trajectories of internalising or externalising behaviours could be divided into three to five groups. This study tested models with two to six groups respectively with one predetermined rule that all trajectories were quadratic (the baseline model) as suggested by Nagin (2005). The best model, selected using the criteria (a) to (g) described as below, determined the final number of groups (Tables 2, 4 and 6). Once the number of groups was decided, the model polynomial characteristics illustrated by different combinations of a constant, linear, and quadratic function of age were then tested. Nagin (2005, p75-77) recommended that fewer groups "with no more groups than is necessary to communicate the distinct features of the data" are preferred for reasons of "parsimony and

comprehensibility." Additionally, several criteria were used to find the best-fitted model (Nylund-Gibson & Choi, 2018):

(a) Bayesian Information Criterion (BIC): A larger BIC score suggests a better fit for the data. The BIC difference ranges from zero to two suggests weak evidence for model improvement. A difference ranges from two to six is regarded as a positive sign that worth noticing. A difference from six to 10 presents strong evidence for model improvement, and a difference of more than 10 is considered very strong evidence (Raftery, 1995).

The present study examined the BIC value differences of models. A model whose BIC score was more than that of the baseline model (i.e., all groups followed the quadratic formula) by six or higher was considered a better-fit model. If the difference between the BIC values of two models was less than six, other diagnostic statistics were used to gauge the fitness of models, including the proportion of each group in the sample (πj; P), Average Posterior Probability of Assignment (AvePP), and Odds of Correct Classification (OCC). Two estimates for the proportion of each group in the sample were provided through different methods: πj was calculated through the formulation explained by Nagin (2005, p41); P was the proportion of the sample assigned to a particular group by the maximum posterior assignment rule. AvePP of a group was an average of the posterior probabilities of individuals assigned to the group. OCC implied the assignment accuracy, larger values for OCC indicated better assignment accuracy (Hickson et al., 2020; Nagin & Odgers, 2010; Nagin, 2005).

(b) 5% or more than 5% of the population in each group ($P \geq 5\%$)

(c) A close correspondence between πj and P

(d) Ideally, AvePP of each group should be no less than 0.7

(e) Ideally, OCC should exceed a minimum threshold of 5 for all groups

(f) The highest-order polynomial coefficient should be significant at .05 level

(g) No polynomial overfitting (e.g., horizontal line modelled as quadratic)

4.2 Results

4.2.1 Group Based Trajectory Modelling

Descriptive and Correlation Analyses (unweighted data)

Table 1 presented tetrachoric correlations and descriptive statistics for internalizing problems, conduct problems and hyperactivity / inattention when children were at an average age of 37.75 months (SD = 2.50), 62.66 months (SD = 2.97), 86.85 months (SD = 3.04) and 133.40 months (SD = 4.09). The results showed that children's internalising problems, conduct problems, and hyperactivity / inattention were positively correlated (all $p < .01$), as expected. The proportion of children under the risk of internalising problems ranged from 22.79% to 29.70% across the four sweeps. In total, 51.24% of 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%.

Table 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

Internalising Problems

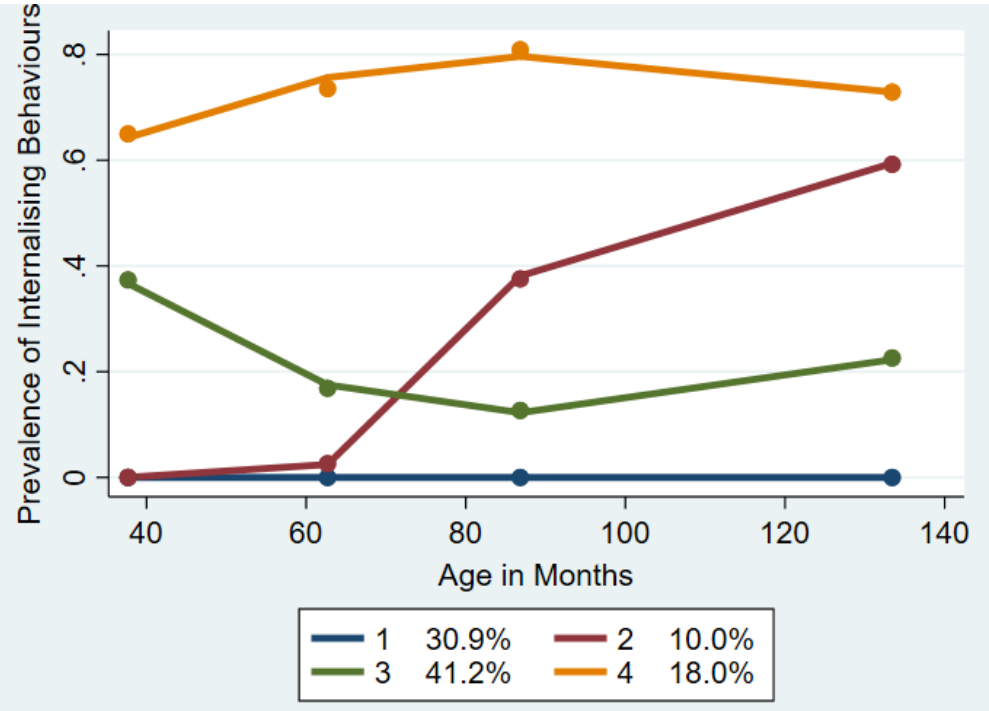
For the GBTM of internalising problems, data on 14,226 children (total N of observations = 50,778) were used. The model fit indices of the two to six group solutions were shown in Table 2. BIC values indicated that the four-group model was better than the other models.

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 3 summarizes the fit indices of these 32 four-group models. The model selected, i.e., the (0 2 2 2) model was the one with the largest BIC value and where the highest-order coefficients for each group were all significant.

Figure 6 describes the four trajectory groups: 'no risk' (30.9% of the sample), 'deteriorating' (10%), 'low risk' (41.2%), and 'high risk' (18%). The children assigned to the 'no risk' group seemed never to 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 of children at risk of internalising problems was approximately between 10% and 40%. The 'high risk' group exhibited a relatively high proportion of high scorers (> 60%) consistently during childhood.

Figure 6

Trajectory Groups of Internalising Problems from Ages 3 to 11 Years



Note. 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.

Table 2

Fit Indices of The Four- to Six-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 3

Fit Indices of the Four-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	*Πj*	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 combinations 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)

Conduct Problems

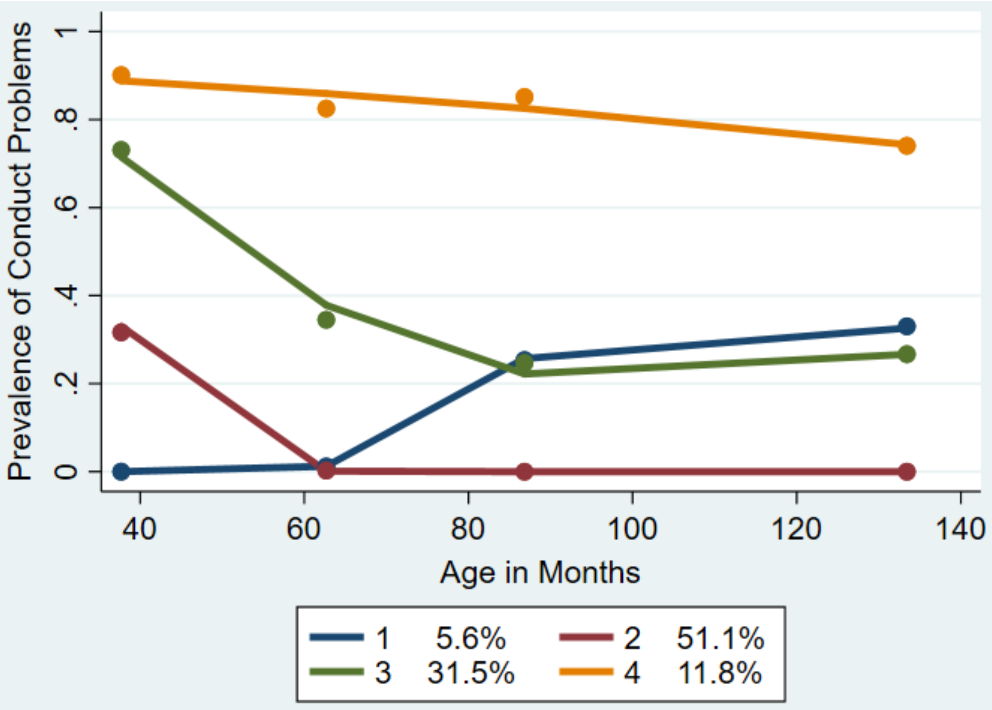
For the GBTM of conduct problems, data on 14,242 children (total N of observations = 50,918) were used. Again, the four-group solution showed a better fit than solutions with two, three, five, or six groups (Table 4).

A total of 38 four-group models were subsequently assessed. In 16 models, each group was modelled as a linear or quadratic function of age. Other 22 models each have up to two groups modelled as a constant function of age, as some studies (e.g., Fanti, 2010; Gutman et al., 2019; Korhonen et al., 2018) have suggested the presence of distinct groups with consistently high and consistently low symptoms. Results were shown in Table 5. The results indicated that the (2 2 2 1) model, (2 2 2 0) model, and (2 2 1 2) model were all improved models compared to the baseline model (2 2 2 2). However, the latter two models, although having more acceptable statistics for AvePP (all > 70%) and OCC (all > 5), generated a nonsymmetric or highly singular variance matrix. Therefore, (2 2 2 1) model was chosen.

Figure 7 depicts the four trajectories according to the best group solution. The 'deteriorating' group (5.6%) showed an increase in the proportion of high scorers, i.e., the proportion of children at risk of conduct problems increased from 0% at age 3 to around 30% at age 11. In the 'early childhood limited' group (51.1%), the proportion of children at risk decreased from about 30% at age 3 to about 0% at age 5, and it 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% at all test time points.

Figure 7

Trajectory Groups of Conduct Problems from Ages 3 to 11 Years



Note. 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.

Table 4

Fit Indices of the Two- to Six-group Solutions for Conduct Problems

Number of Groups	BIC (N*=50918)	BIC (N*=14242)	AvePP	OCC	P	*Πj*	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 5

Fit Indices of the Four-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

Table 5 continued

Model	BIC (N*=50918)	BIC (N*=14242)	AvePP	OCC	P	*Πj*	The Highest Order Coefficient Significant
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)

Hyperactivity / inattention

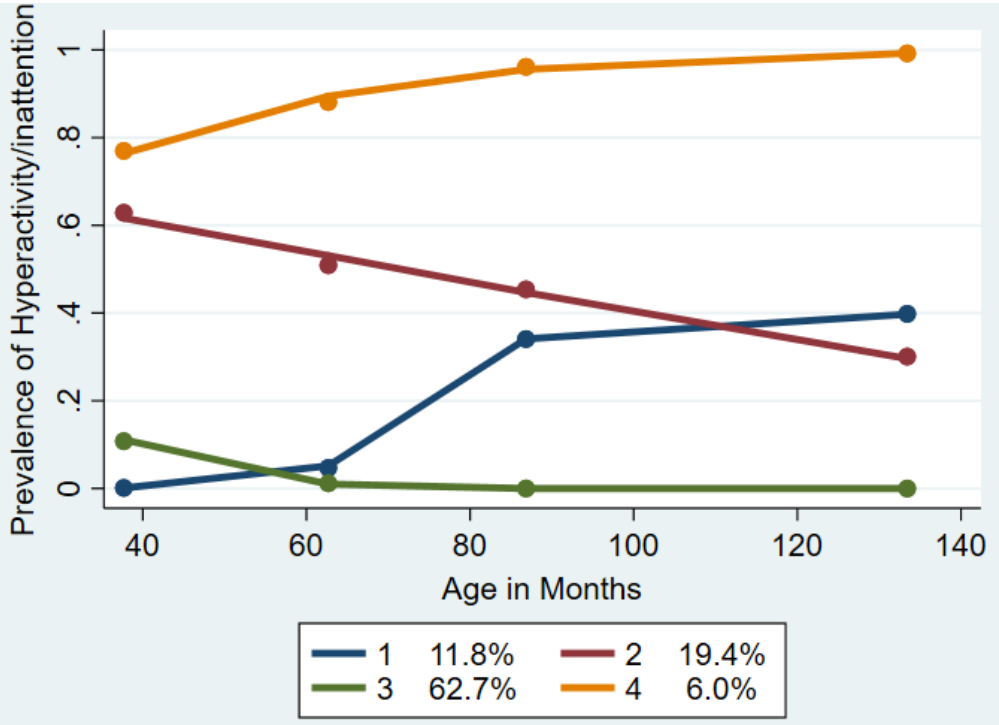
For the GBTM of hyperactivity / inattention, data on 14,249 children (total N of observations = 50,920) were used. Again, the four-group model showed the largest BIC value, which was higher than that of other models by at least nine, suggesting strong evidence for model improvement (Table 6).

Thirty-eight four-group models with different combinations of a polynomial function of age across four groups were tested, and their fit indices are presented in Table 7. (1 2 2 2) model, (2 1 2 2) model, and (2 1 2 1) model were improved models compared to the baseline model. (2 1 2 1) was selected as the final model for hyperactivity / inattention. Although the BIC value of (2 1 2 1) model was five less than that of the other two models, which implied a moderately worse model fit, it was selected because, firstly, its AvePP for each group were all more than 0.7; secondly, the differences between P and πj were 0.04, 0.05, 0.09 and 0.01 for four groups respectively while, in the other two models, there were two groups showed the P-πj difference of 0.09.

Figure 8 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 of children at risk of hyperactivity / inattention 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 after that until age 11. Finally, the 'high risk' group (6%) had a very high proportion of high scorers, which increased from about 80% at age 3 to 100% at age 11.

Figure 8

Trajectory Groups of Hyperactivity / inattention from Ages 3 to 11 Years



Note. 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.

Table 6

Fit Indices of the Two- to Six-group Solutions for Hyperactivity / inattention

Number of Groups	BIC (N*=50920)	BIC (N*=14249)	AvePP	OCC	P	*Πj*	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

Table 7

Fit Indices of the Four-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

Table 7 Continued

Model	BIC (N*=50920)	BIC (N*=14249)	AvePP	OCC	P	*Πj*	The Highest Order Coefficient Significant
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 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)

4.2.2 Multiple Regression Modelling

Bias analysis (unweighted data)

The normality tests i.e., Shapiro-Wilk test were conducted for continuous variables. The results showed a significant departure from normality for all the tested variables including children's age [W (13,468) = 1.00, P < .001], verbal ability [W (13,167) = 0.97, P < .001], maternal depression [W (16,950) = 0.97, P < .001], family poverty [W (17,542) = 0.98, P < .001], SWM total errors [W (12,756) = 0.99, P < .001] and SWM strategy [W (12,756) = 0.86, P < .001]. Even so, the independent t-test[3] and linear regression were still used as those tests do not require the assumption of normal distribution in sufficiently large samples (Lumley et al., 2002). Levene's tests were used to test the homogeneity of variance of those continuous variables in the analytic and non-analytic samples. The test results indicated unequal variances for children's age [F (1, 13,467) = 26.71, P < .001], verbal ability [F (1, 13,166) = 12.78, P < .001], maternal depression [F (1, 16,949) = 1.2210e+02, P < .001], family poverty [F (1, 17,541) = 700.94, P < .001]; while equal variances were found for SWM total errors [F (1, 12,755) = 0.20, P = 0.65] and SWM strategy [F (1, 12,755) = 0.01, P = 0.92]. Therefore, t values with equal variance assumed were reported below for SWM, while for other variables the ones with equal variance not assumed were reported.

[3] As figure 4 illustrated, the sample for multiple regression analyses (i.e., the analytic sample) was children (singletons and first-born multiples) with data on SWM at age 11 years. Children who were not included in the analytic sample (e.g., children with no data on SWM; children who are not first-born twins / triplets) constituted the non-analytic sample. To test sample selection bias, t tests were used to determine whether the analytic sample is significantly different from the non-analytic sample.

Comparison of the sample characteristics between the analytic and non-analytic samples indicated children in the two samples shared similarity in SWM, verbal ability, and the ratios of trajectory groups of problem behaviours. Similarly, maternal depression showed no significant difference. However, the comparison demonstrated some sample selection bias (Table 8). Children in the analytic sample were slightly older than children in the non-analytic sample. Children in the analytic sample were less likely to be from a family below the poverty line and more likely to be female, white, and have a mother with a university degree.

Table 8

Descriptives of study variables in the analytic sample and the non-analytic sample (unweighted data)

	Analytic Sample (N = 12,589)		Non-analytic sample (N = 6,900)			
Continuous variables	N	Mean (SE)	N	Mean (SE)	*t*	*p*
SWM total errors	12,589	35.68 (0.17)	168	37.80 (1.53)	1.45	0.15
SWM strategy	12,589	34.32 (0.05)	168	34.59 (0.44)	0.61	0.54
Age in months	12,589	133.44 (0.04)	880	132.82 (0.17)	-3.49	0.0005
Poverty	12,589	0.30 (0.003)	4,954	0.40 (0.01)	14.09	0.0000
Maternal depression	12,318	0.22 (0.003)	4,633	0.22 (0.005)	-0.13	0.90
Verbal ability	12,476	58.68 (0.09)	692	58.71 (0.44)	0.05	0.96
Categorical variables	N	%	N	%	$\chi 2$	*p*
No risk group of internalising problems	5,300	46.8	64	42.1	1.56	0.67
Early childhood limited group of conduct problems	7,249	64.4	42	64.6	1.02	0.80
Typically developing group of hyperactivity / inattention	7,939	70.1	108	71.1	6.13	0.11
Female	6,270	49.8	408	46.4	3.90	0.048
White	10,469	83.2	684	77.8	24.00	0.000
Mother has 1st degree	2,235	18.4	711	10.8	190.31	0.000

t tests were used to determine whether two populations, i.e., the analytic sample and the non-analytic sample, are statistically different from each other.
t: t value for independent samples t-test
$\chi 2$: person's Chi-Square

Sample characteristics (unweighted data)

Table 9 indicates that the two measures for SWM were moderately correlated ($r = 0.65$, $p < .05$), as expected. Tables 10, 11, and 12 present the analytic sample's characteristics by trajectory group. As expected, the children in 'high risk' groups showed more average SWM errors and less efficient strategy than 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. One-way between subject ANOVA was conducted to determine whether children's SWM skills differ across trajectory groups of three domains of child psychopathology. Regression would not be necessary if ANOVA results indicate no significant group difference at all. For SWM skills measured by SWM total errors, there was a significant between-group difference among trajectory groups of internalising problems, $F (3, 11325) = 73.39$, $p < .001$. Post-hoc pairwise comparisons of means are commonly performed after significant effects to identify which pairs of groups show significant differences. The Bonferroni test, one of the build-in post-hoc tests in STATA, revealed that the 'no risk' group scored significantly lower than any other three groups, indicating stronger SWM skills. The 'high risk' group showed significantly worse SWM skills than the other three groups, while no significant group difference in SWM total errors was reported between the 'deteriorating group and the 'low risk' group (Table 10). A significant between-group difference in SWM total errors was also detected among trajectory groups of conduct problems, $F (3, 11246) = 68.61$, $p < .001$. The Bonferroni post hoc test results reported significant differences in SWM total errors were found between

the ‘high risk’ group and any of the other three groups as well as between the ‘early childhood limited’ group and the ‘improving’ group (Table 11). Among the trajectory groups of hyperactivity / inattention, at least one pair of groups showed a significant difference in SWM total errors, $F (3, 11327) = 129.85$, $p < .001$. The Bonferroni test results suggested significant group differences among all groups except for the ‘deteriorating’ group and the ‘improving’ group (Table 12). For SWM skills measured by SWM strategy, there was a significant between-group difference among the trajectory groups of internalising problems, $F (3, 11325) = 22.05$, $p < .001$. The Bonferroni test results indicated the ‘no risk’ group showed a significantly more efficient SWM strategy than any other three groups. The ‘high risk’ group performed significantly worse than the ‘low risk’ group while there was no significant group difference between the ‘deteriorating’ group and the ‘low risk’ or ‘high risk’ group (Table 10). Among the trajectory groups of conduct problems, there were significant between-group differences for the SWM strategy, $F (3, 11246) = 28.42$, $p < .001$. The Bonferroni test results revealed significant group differences between the following three pairs of groups – the ‘early childhood limited’ and the ‘improving’ group; the ‘early childhood limited’ and the ‘high risk’ group; the ‘improving’ and the ‘high risk’ group. No significant group difference was found between the ‘deteriorating’ group and any other three groups (Table 11). There was significant between-group difference among hyperactivity / inattention trajectory groups, $F (3, 11327) = 49.94$, $p < .001$. According to the Bonferroni test results, all the groups differ significantly in terms of SWM strategy scores except for the ‘deteriorating’ group and the ‘improving’ group (Table 12).

The children in groups with the lowest average prevalence of problem behaviours 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 trajectory 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).

Table 9

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

This study intended to investigate the first research question (i.e., *What is the relationship between the development of child psychopathology and later SWM performance*?) using regression models where SWM is the dependent variable and child psychopathology is the independent variable. According to the PPCT model proposed by the bioecological theory of human development (as explained in Chapter 2), variables of child characteristics and variables of the proximal and distal context were added to the regression models successively. Four models were fitted for each SWM domain (errors and strategy) and each symptom domain (internalising, conduct, and hyperactivity / inattention). The baseline model (Model 1) only included trajectory group membership, which is the independent

variable. 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. Verbal ability is a measure which asked children to describe and summarise the similarity among three words after hearing them, reflecting children's verbal reasoning skills (Elliott et al., 1996). Reasoning, as a broad concept of higher-level cognitive skills, is reported to be involved in any complex cognitive tasks (Jarrold & Towse, 2006). This study included verbal ability, as a proxy of reasoning, in the model to account for individual differences in SWM caused by differences in the reasoning ability. In the meantime, according to the framework of executive functions, reasoning, as a higher-level executive function, is built on core executive functions including working memory (Diamond, 2013), as such, measures of reasoning and measures of working memory would be to some extent correlated. Hence, verbal ability as a variable reflecting reasoning skill was added last to the model, allowing us to establish the effect of SWM while, ideally, all known predictors are controlled for (i.e., the net effect of SWM). In all models, trajectory group membership, a categorical variable, was included as one of the explanatory variables. Given that the present study is interested in the relationship between child psychopathology and SWM and the literature review tended to suggest a positive relationship – lower levels of problem behaviours are related to stronger SWM skills, the group with the average lowest prevalence of problem behaviours was taken as the reference group; hence no coefficients are reported for that group. The regression models presented in this chapter dealt with the sample design using the "*svy*" command, and the missingness using multiple imputation commands, as explained. As a result, it was not possible to obtain R^2, the statistical measure that represents the proportion of the

variance for a dependent variable explained by independent variables. The author ran the same regression models without using multiple imputation commands to obtain R^2, and the regression modelling results were tabulated in Tables S13-S18 in Appendix 4. Missing data could lead to the probability that the null hypothesis is rejected when it is false (i.e., p-value less than .05 or .01), because, firstly, the sample becomes by definition more selective and, secondly, the statistical power is depleted. Indeed, when exploring the relationship between internalising behaviours and SWM strategy, some of the independent variables' regression coefficients became significant in the final model when the missingness was not dealt with (Tables 14 & S14). Therefore, it is important data missingness is dealt with in data analysis.

Table 10

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

The 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. The F-test assesses the amount of variability between the group means in the context of the variation within groups to determine whether the mean differences are statistically significant. The Chi-square test is commonly used to test the difference in the distribution of categorical variables between two or more independent groups.

Effect size: Eta-Squared for continuous variables and Cramer's V for categorical variables

Table 11

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

The 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. The F-test assesses the amount of variability between the group means in the context of the variation within groups to determine whether the mean differences are statistically significant. The Chi-square test is commonly used to test the difference in the distribution of categorical variables between two or more independent groups.

Effect size: Eta-Squared for continuous variables and Cramer's V for categorical variables

Table 12

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. The F-test assesses the amount of variability between the group means in the context of the variation within groups to determine whether the mean differences are statistically significant. The Chi-square test is commonly used to test the difference in the distribution of categorical variables between two or more independent groups.

Effect size: Eta-Squared for continuous variables and Cramer's V for categorical variables

Internalising Problems and SWM

Multiple regressions were run to test whether the trajectory group membership of internalising problems predicts children's SWM performance at age 11. The results in Table 13, which show differences in SWM by internalising trajectory group, suggest that children from the 'high risk' group ($\beta = 0.17$, $p<.001$), the 'low risk' group ($\beta = 0.07$, $p<.001$) and the 'deteriorating' group ($\beta = 0.14$, $p<.001$) made significantly more search errors in the SWM task than children from the 'no risk' group, even after controlling for covariates. Being female, higher levels of verbal ability, and having a university-educated mother linked with fewer total errors, whereas poverty and being Black or Black British were associated with more total errors. Similar results were displayed about the protective / risk factors for SWM strategy except that there was no significant gender difference regarding SWM strategy. Trajectory group membership of internalising problems had little impact on SWM strategy (Table 14). After full adjustment, children's SWM strategy performance no longer differed between the 'no risk' groups and any other internalising trajectory groups.

Table 13

Regression Estimates [unstandardised coefficients (SE) & standardised coefficients] of Internalising Problem Group Membership on SWM Total Errors

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Internalising Behaviours (Ref: No risk)								
Deteriorating	4.69 (.89) ***	0.25***	4.23 (.89) ***	0.23***	3.09 (.89) ***	0.16***	2.60 (.92) **	0.14***
Low risk	3.14 (.51) ***	0.17***	3.19 (.51) ***	0.17***	1.76 (.50) ***	0.09***	1.33 (.50) **	0.07***
High risk	7.15 (.56) ***	0.38***	7.03 (.55) ***	0.38***	4.30 (.62) ***	0.23***	3.09 (.60) ***	0.17***
Age at Sweep 5			-.31 (.06) ***	-0.07***	-0.32 (.06) ***	-0.07***	-0.35 (.05) ***	-0.07***
Gender (Ref: Male)								
Female			-1.10 (.39) **	-0.06**	-1.16 (.37) **	-0.06***	-1.33 (.37) ***	-0.07***
Poverty					6.14 (.63) ***	0.12***	4.58 (.66) ***	0.09***
Ethnicity (Ref: White)								
Mixed					.76 (1.38)	0.04	1.23 (1.37)	0.07
Indian					-.02 (1.57)	-0.00	0.98 (1.62)	0.05
Pakistani and Bangladeshi					.86 (.92)	0.05	0.42 (1.06)	0.02
Black or Black British					5.48 (1.54) ***	0.29***	6.23 (1.48) ***	0.33***
Other (Inc Chinese)					-2.70 (1.74)	-0.14	-2.31 (1.76)	-0.12
Maternal Education								
Has 1st degree					-6.10 (.54) ***	-0.33***	-4.85 (.56) ***	-0.26***
Maternal Depression					1.00 (.79)	0.02	1.09 (.76)	0.02

Table 13 Continued

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Verbal ability							-.32 (.02) ***	-0.17***
Constant	33.15 (.33) ***		74.96 (7.57) ***		76.31 (7.43) ***		98.75 (6.97) ***	

Reference group: the 'no risk' group. *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 14

Regression Estimates [unstandardised coefficients (SE) & standardised coefficients] of Internalising Problem Group Membership on SWM Strategy

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Internalising Behaviours (Ref: No risk)								
Deteriorating	.81 (.30) **	0.14**	.73 (.30) *	0.12*	.45 (.30)	0.07	.36 (.30)	0.06
Low risk	.69 (.15) ***	0.12***	.71 (.15) ***	0.12***	.37 (.15) *	0.06*	.29 (.15)	0.05
High risk	1.13 (.19) ***	0.19***	1.13 (.19) ***	0.19***	.48 (.19) *	0.08*	.29 (.20)	0.05
Age at Sweep 5			-.06 (.02) ***	-0.04***	-.06 (.02) ***	-0.04***	-.09 (.02) ***	-0.06***
Gender (Ref: Male)								
Female			.13 (.13)	0.02	.12 (.12)	0.02	.06 (.12)	0.01

Table 14 Continued

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**B**	**B (SE)**	**β**
Poverty					1.08 (.19) ***	0.07***	.69 (.19) ***	0.04***
Ethnicity (Ref: White)								
Mixed					.01 (.38)	0.00	.09 (.38)	0.02
Indian					-.45 (.53)	-0.08	-.19 (.53)	-0.03
Pakistani and Bangladeshi					.53 (.29)	0.09	.40 (.31)	0.07
Black or Black British					.88 (.37) *	0.15*	1.00 (.35) **	0.17**
Other (Inc Chinese)					-.79 (.60)	-0.13	-.66 (.63)	-0.11
Maternal Education								
Has 1st degree					-1.82 (.19) ***	-0.31***	-1.50 (.21) ***	-0.25***
Maternal Depression					.37 (.22)	0.02	.41 (.21)	0.02
Verbal ability							-.08 (.01) ***	-0.13***
Constant	33.85 (.10) ***		41.82 (2.34) ***		42.30 (2.30) ***		50.40 (2.24) ***	

Reference group: the 'no risk' group. *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)

Conduct Problems and SWM

Multiple regressions were run to test whether the trajectory group membership of conduct problems predicts children's SWM performance at age 11. Results in Table 15 indicate that the 'improving' group ($\beta = 0.07$, $p<0.001$) and the 'high risk' group ($\beta = 0.17$, $p<0.001$) made more errors than the 'early childhood limited' group. Compared to the 'early childhood limited' group, the 'improving' group ($\beta = 0.06$, $p <0.05$) and the 'high-risk' group ($\beta = 0.12$, $p<0.001$) also showed poorer SWM strategy (Table 16). The 'deteriorating' group, however, showed similar performance on either SWM total errors ($\beta = 0.03$, $p>0.05$) or SWM strategy ($\beta = 0.08$, $p>0.05$) compared to the 'early childhood limited' group. Similar to what was reported previously, higher levels of verbal ability and having a mother with 1st degree are protective factors for children's SWM development, i.e., fewer search errors in the SWM task, more efficient search strategies. Risk factors for the development of children's SWM skills include poverty and being Black or Black British. Girls tend to make fewer search errors than boys in the SWM task, but there is no gender difference in using SWM strategies.

Hyperactivity / inattention and SWM

Multiple regressions were also run to test whether the trajectory group membership of hyperactivity / inattention predicts children's SWM performance at age 11. 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 both SWM errors and SWM strategy (Table 17 & Table 18), with the 'high risk' group performing particularly

poorly. The results also showed the same protective / risk factors for children's SWM skills as described in the former paragraphs.

Table 15

Regression Estimates [unstandardised coefficients (SE) & standardised coefficients] of Conduct Problem Group Membership on SWM Total Errors

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**B**	**B (SE)**	**B**
Conduct Problems (Ref: Early childhood limited)								
Deteriorating	2.13 (1.14)	0.11	1.81 (1.15)	0.10	1.06 (1.12)	0.06	.50 (1.10)	0.03
Improving	3.70 (.55) ***	0.20***	3.66 (.55) ***	0.20***	1.93 (.55) ***	0.10***	1.38 (.52) **	0.07***
High risk	7.03 (.64) ***	0.37***	6.76 (.63) ***	0.36***	4.23 (.70) ***	0.23***	3.25 (.66) ***	0.17***
Age at Sweep 5			-.30 (.06) ***	-0.06***	-.32 (.06) ***	-0.07***	-.35 (.05) ***	-0.07***
Gender (Ref: Male)								
Female			-.80 (.39) *	-0.04***	-.96 (.37) *	-0.05***	-1.18 (.37) **	-0.06***
Poverty					5.99 (.64) ***	0.12***	4.45 (.66) ***	0.09***
Ethnicity (Ref: White)								
Mixed					.94 (1.38)	0.05	1.36 (1.36)	0.07
Indian					.58 (1.57)	0.03	1.42 (1.63)	0.08
Pakistani and Bangladeshi					1.72 (.91)	0.09	1.05 (1.06)	0.06
Black or Black British					5.86 (1.48) ***	0.31***	6.50 (1.43) ***	0.35***
Other (Inc Chinese)					-2.32 (1.71)	-0.12	-2.04 (1.72)	-0.11
Maternal Education								
Has 1st degree					-6.10 (.56) ***	-0.33***	-4.85 (.58) ***	-0.26***
Maternal Depression					1.33 (.77)	0.02	1.31 (.74)	0.02
Verbal ability							-.32 (.02) ***	-0.17***

Table 15 Continued

	Model 1	Model 2	Model 3	Model 4
Constant	33.88 (.32) ***	74.93 (7.64) ***	76.48 (7.46) ***	99.06 (7.00) ***

Reference group: the 'early childhood limited' group. *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 16

Regression Estimates [unstandardised coefficients (SE) & standardised coefficients] of Conduct Problem Group Membership on SWM Strategy

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Conduct Problems (Ref: Early childhood limited)								
Deteriorating	.89 (.32) **	0.15**	.84 (.32) **	0.14**	.66 (.31) *	0.11**	.49 (.30)	0.08
Improving	.79 (.17) ***	0.13***	.80 (.17) ***	0.13***	.42 (.17) *	0.07*	.33 (.16) *	0.06*
High risk	1.40 (.22) ***	0.24***	1.40 (.22) ***	0.24***	.84 (.23) ***	0.14***	.70 (.21) **	0.12***
Age at Sweep 5			-.06 (.02) **	-0.04**	-.06 (.02) **	-0.04**	-.09 (.02) ***	-0.06**
Gender (Ref: Male)								
Female			.20 (.13)	0.03	.17 (.12)	0.03	.11 (.12)	0.02
Poverty					1.01 (.18) ***	0.06***	.62 (.18) ***	0.04***
Ethnicity (Ref: White)								
Mixed					.02 (.38)	0.00	.09 (.38)	0.02
Indian					-.34 (.53)	-0.06	-.11 (.54)	-0.02
Pakistani and Bangladeshi					.67 (.29) *	0.11*	.51 (.30)	0.09

Table 16 Continued

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Black or Black British					.96 (.36) **	0.16**	1.06 (.35) **	0.18**
Other (Inc Chinese)					-.72 (.61)	-0.12	-.60 (.63)	-0.10
Maternal Education								
Has 1st degree					-1.82 (.19) ***	-0.31***	-1.51 (.21) ***	-0.25***
Maternal Depression					.32 (.21)	0.02	.34 (.21)	0.02
Verbal ability							-.08 (.01) ***	-0.13***
Constant	33.93 (.09) ***		41.42 (2.32) ***		41.95 (2.28) ***		49.98 (2.23) ***	

Reference group: the 'early childhood limited' group. *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 17

Regression Estimates [unstandardised coefficients (SE) & standardised coefficients] of Hyperactivity / inattention Group Membership on SWM Total Errors

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Hyperactivity / inattention (Ref: Typically developing)								
Deteriorating	5.68 (.72) ***	0.30***	5.49 (.73) ***	0.29***	4.31 (.70) ***	0.23***	3.59 (.71) ***	0.19***
Improving	5.55 (.59) ***	0.30***	5.50 (.59) ***	0.29***	3.55 (.60) ***	0.19***	2.88 (.59) ***	0.15***
High risk	10.04 (.87) ***	0.54***	9.81 (.86) ***	0.52***	7.63 (.92) ***	0.41***	5.80 (.80) ***	0.31***
Age at Sweep 5			-.30 (.06) ***	-0.06***	-.31 (.05) ***	-0.07***	-.34 (.05) ***	-0.07***
Gender (Ref: Male)								
Female			-.39 (.39)	-0.02	-.59 (.38)	-0.03	-.88 (.37) *	-0.05*
Poverty					5.92 (.62) ***	0.12***	4.44 (.65) ***	0.09***
Ethnicity (Ref: White)								
Mixed					.93 (1.38)	0.05	1.32 (1.36)	0.07
Indian					.47 (1.56)	0.02	1.28 (1.62)	0.07
Pakistani and Bangladeshi					1.53 (.94)	0.08	.92 (1.07)	0.05
Black or Black British					6.01 (1.50) ***	0.32***	6.59 (1.44) ***	0.35***
Other (Inc Chinese)					-1.94 (1.67)	-0.10	-1.77 (1.69)	-0.09
Maternal Education								
Has 1st degree					-5.84 (.56) ***	-0.31***	-4.68 (.58) ***	-0.25***
Maternal Depression					.82 (.76)	0.01	.90 (.74)	0.02
Verbal ability							-.31 (.02) ***	-0.16***
Constant	33.55 (.29) ***		73.70 (7.55) ***		74.78 (7.36) ***		96.65 (7.02) ***	

Reference group: the 'typically developing' group. *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 18

Regression Estimates [unstandardised coefficients (SE) & standardised coefficients] of Hyperactivity / inattention Group Membership on SWM Strategy

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**B**	**B (SE)**	**β**
Hyperactivity / inattention (Ref: Typically developing)								
Deteriorating	1.10 (.23) ***	0.18***	1.10 (.23) ***	0.19***	.82 (.22) ***	0.14***	.63 (.23) **	0.11**
Improving	1.25 (.18) ***	0.21***	1.27 (.18) ***	0.21***	.82 (.19) ***	0.14***	.65 (.19) ***	0.11***
High risk	1.67 (.25) ***	0.28***	1.70 (.25) ***	0.29***	1.19 (.26) ***	0.20***	1.06 (.24) ***	0.18***
Age at Sweep 5			-.06 (.02) **	-0.04**	-.06 (.02) **	-0.04**	-.09 (.02) ***	-0.06**
Gender (Ref: Male)								
Female			.27 (.13) *	0.05*	.22 (.12)	0.04	.16 (.12)	0.03
Poverty					1.00 (.19) ***	0.06***	.63 (.19) ***	0.04***
Ethnicity (Ref: White)								
Mixed					.01 (.38)	0.00	.07 (.38)	0.01
Indian					-.38 (.52)	-0.06	-.15 (.53)	-0.03
Pakistani and Bangladeshi					.61 (.29) *	0.10*	.47 (.31)	0.08
Black or Black British					.98 (.36) **	0.17**	1.07 (.35) **	0.18**
Other (Inc Chinese)					-.66 (.60)	-0.11	-.56 (.62)	-0.09
Maternal Education								
Has 1st degree					-1.78 (.19) ***	-0.30***	-1.48 (.21) ***	-0.25***
Maternal Depression					.26 (.22)	0.01	.28 (.21)	0.02
Verbal ability							-.07 (.01) ***	-0.12***
Constant	33.90 (.08) ***		41.40 (2.33) ***		41.84 (2.28) ***		49.73 (2.21) ***	

Reference group: the 'typically developing' group. *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)

4.3 Summary of Group Based Trajectory Modelling and Multiple Regression Modelling Results

Group Based Trajectory Modelling was conducted separately for all three domains of child psychopathology, i.e., internalising problems, conduct problems, and hyperactivity / inattention. Four trajectory groups emerged from the data across these three domains. It is consistent with the longitudinal studies following a large general-population sample at similar age points (e.g., Flouri et al., 2018, Gutman et al., 2019). In general, for each child psychopathology domain, there was

- *one group* with nearly none or lower than 30% of children at risk of developing problem behaviours from age 3 to age 11, i.e., the 'no risk' group of internalising problems, the 'early childhood limited' group of conduct problems, and the 'typically developing' group of hyperactivity / inattention. This group with the lowest average level of problem behaviours was used as the reference group in the subsequent regression analysis, to which the largest proportion of children belong.
- *one group* showed a fluctuating proportion of children at risk of problem behaviours, i.e., the 'low risk' group of internalising problems, the 'improving' group of conduct problems, and the 'improving' group of hyperactivity / inattention. Nevertheless, the situation in general was not of concern as the proportion was decreasing over the years and / or very low.
- *one 'deteriorating' group* where the proportion of children at risk of problem behaviours increased over the years.

- alarmingly, *one group* illustrating a persistently high proportion of children who were at risk of problem behaviours i.e., the 'high risk' group for all three domains of child psychopathology. If a child was assigned to the 'high risk' group for all three child psychopathology domains, it suggests, at the age of 11, his chances of displaying parent-reported internalising behaviour and conduct problems were both more than 70%, and the probability for hyperactivity / inattention behaviours was 100%.

Multiple regression modelling was conducted where the independent variable (i.e., predictor) was, respectively, trajectory group membership of internalising problems, trajectory group membership of conduct problems, and trajectory group membership of hyperactivity / inattention. The multiple regression results indicated:

- When the independent variable was trajectory group membership of internalising problems, children from the 'high risk', the 'deteriorating', and the 'low risk' groups made significantly more SWM total errors indicating poorer SWM performance compared to children from the 'no risk' group, even after controlling for all covariates (Table 13). However, when SWM was measured by SWM strategy, the group difference between the 'deteriorating' and the 'no risk' disappeared when family characteristics, e.g., SES, maternal education, and maternal depression, were accounted for; the group differences between the 'high risk' / the 'low risk' and the 'no risk' were no longer significant when children's verbal reasoning ability was considered (Table 14).
- When the predictor was trajectory group membership of conduct problems, children from the 'high risk' and the 'improving' groups showed significantly

poorer performance on both SWM total errors and SWM strategy than children from the 'early childhood limited' group, after controlling for all covariates (Table 15 & Table 16). However, children from the 'deteriorating' group showed no significant difference to children of the 'early childhood limited' group in terms of SWM total errors even in the baseline model (Table 15). The significant difference in SWM strategy between the 'deteriorating' and the 'early childhood limited' group became insignificant after children's verbal reasoning ability was controlled for (Table 16). The 'high risk' group performed significantly worse on SWM total errors than the 'deteriorating' group and the 'improving' group (Table 15), but not on SWM strategy (Table 16).

- When the predictor was trajectory group membership of hyperactivity / inattention, children from 'the high risk', 'the deteriorating', and the 'improving' groups of hyperactivity / inattention, compared with children in the 'typically developing' group, showed significantly poorer SWM performance regardless of SWM measures (Table 17 & Table 18).
- While no gender difference was found for children's use of SWM strategy, girls tended to outperform boys on making fewer errors during the SWM test.
- Risk factors for 11-year olds' SWM, measured by both total errors and strategy, were poverty, being Black or Black British, mother having no 1st degree, and poorer children's verbal reasoning ability.

Chapter 5

Child Psychopathology, Spatial Working Memory and Academic Performance - A Mediation Analysis

Child psychopathology symptoms could predict children's academic performance (see Chapter 2 of the present study for more detail). SWM could potentially play a role in explaining the impact of child psychopathology on academic performance by subject. Firstly, the previous analysis of the present study indicated that reported child psychopathology symptoms were associated with SWM performance in early adolescence. Children at risk of chronic behavioural problems from age 3 to age 11 consistently showed poorer SWM skills at age 11 across the three domains of child psychopathology. Secondly, some researchers (e.g., Aronen et al., 2005; Soltanlou et al., 2019) have found that children's SWM skills tend to predict their academic performance at school. But SMW as a mediator of the link between children's psychopathology and their academic performance has not been formally tested. Therefore, the present study conducted a mediation analysis to explore whether SWM may mediate some of the effects between child psychopathology symptoms and academic performance i.e., the pathway of child psychopathology symptoms – SWM – academic performance. Such mediation analysis will improve the understanding of one of the underlying mechanisms, which is pertinent to the work of professionals working in the field of educational psychology.

5.1 Methodology

5.1.1 Sample

Children's academic performance was assessed by a teacher survey. MCS teacher survey was conducted at Sweep 5 when the children were aged 11 and in their final year of primary school, and it was only conducted in England and Wales due to funding constraints (Gallop et al., 2013). Therefore, a sub-sample was obtained from the analytic sample of regression modelling for mediation analysis with the condition that data on children's (singletons and first-born multiples) SWM and academic performance were both available at Sweep 5. The final sample consists of 7147 children.

5.1.2 Measures

Children's academic performance was measured by a question in the teacher survey, which asked teachers to rate the child's ability and attainment in English, maths, and science, respectively, using a 5-point scale, i.e., well above average, above average, average, below average, well below average. A higher point indicated a lower level of academic performance. The present study used data on teacher's ratings on English, maths, and science. ***Children's trajectory group membership of internalising problems / conduct problems / hyperactivity-inattention*** was generated by GBTM using SDQ scores from Sweep 2 to Sweep 5 (for more details see Chapter 3 and Chapter 4). ***SWM*** as the mediator was measured by SWM total errors and SWM strategy as described in Chapter 3.

5.1.3 Analytic Strategy

Mediation analysis estimates the mechanisms between an outcome variable and exploratory variables using two separate regression models – one model considers the outcome variable of interest as the dependent variable, and the other model uses the mediator as the dependent variable (Hicks & Tingley, 2011). The mediation analysis produces coefficients indicating the direct effect, i.e., the effect of an independent variable directly on the outcome variable, and the indirect effect (also known as the mediated effect), i.e., the effect of an independent variable on the outcome variable via a mediator (VanderWeele, 2016). In the context of the present study, the direct and indirect effects can be explained as below:

Y denotes 'children's academic performance'.

X denotes 'children's psychopathology trajectory group membership'.

M denotes the mediator 'SWM'.

C denotes a list of covariates.

$$Y = \theta_1 X + \theta_2 M + \theta_3 C + \theta_0$$

$$M = \beta_1 X + \beta_2 C + \beta_0$$

'θ_1' is the direct effect, i.e., effects of the trajectory group membership of problem behaviours on academic performance.

'$\beta_1 \times \theta_2$' is the indirect effect, i.e., effects of the trajectory group membership of problem behaviours on academic performance mediated by SWM.

The present study used the *sureg* command in STATA for the mediation analysis. It estimated the coefficients in the above two regression equations using seemingly unrelated regression, which allows cross-equation error correlation.

5.2 Results

5.2.1 Descriptive and Correlation Analyses (unweighted data)

Table 19 indicates both SWM measures were significantly correlated with three subjects of children's academic performance at age 11, i.e., English, maths, science. The sizes of correlations were small (r ranges from 0.22 to 0.41, $p < .05$). As expected, children's maths results were more strongly related to SWM compared to English and science results.

Table 19

Pairwise Pearson Correlations and Descriptive Statistics of SWM and Academic Performance at Age 11 (unweighted data)

	English	Maths	Science	SWM total errors	SWM strategy
English	1.00				
Maths	0.78*	1.00			
Science	0.80*	0.82*	1.00		
SWM total errors	0.35*	0.41*	0.37*	1.00	
SWM strategy	0.22*	0.27*	0.24*	0.65*	1.00
Mean (SD)	2.65 (1.01)	2.58 (1.00)	2.62 (0.86)	34.58 (18.51)	34.08 (5.92)
N	7,088	7,071	7,063	7,147	7,147

Note: *p<0.05

Tables 20, 21, and 22 present the analytic sample's SWM and academic performance by trajectory group. As expected, the children in 'high risk' groups consistently showed the highest mean scores across SWM / academic performance measures, suggesting possible poorer SWM / academic performance. 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 academic

performance. A one-way between-subjects ANOVA was conducted to compare the effect of the trajectory group membership of internalising behaviours / conduct problems / hyperactivity-inattention on academic performance in English, maths, and science, respectively. There was a significant effect of internalising problems trajectory group membership on children's English scores [F (3, 6546) = 66.61, p < .001], maths scores [F (3, 6546) = 55.41, p < .001], and science scores [F (3, 6546) = 40.67, p < .001]. Trajectory group membership of conduct problems showed significant between-group effect on children's English scores [F (3, 6471) = 67.82, p < .001], maths scores [F (3, 6471) = 33.99, p < .001], and science scores [F (3, 6471) = 34.05, p < .001]. There was also significant hyperactivity / inattention trajectory group difference in English scores [F (3, 6546) = 128.30, p < .001]. maths scores [F (3, 6546) = 80.67, p < .001], and science scores [F (3, 6546) = 68.34, p < .001]. Post hoc comparisons using the Bonferroni test revealed which pairs of groups showed significant differences (Tables 23, 24, and 25)

Table 20

Distribution of Dependent and Mediation Variables by Trajectory Group of Internalising Problems (unweighted data)

	Total N = 7,147	Range	1. No risk N = 3,022	2. Deteriorating N = 467	3. Low risk N = 1,971	4. High risk N = 1,090	p-value	Effect size
Continuous variables, M (SD)								
English	2.63(1.01)	[1,5]	2.43(0.93)	2.93(1.02)	2.63(1.01)	3.06(1.04)	< 0.001	.05
Maths	2.56(1.00)	[1,5]	2.36(0.94)	2.90(1.06)	2.57(0.98)	2.93(1.03)	< 0.001	.05
Science	2.59(0.85)	[1,5]	2.44(0.79)	2.81(0.90)	2.59(0.84)	2.93(0.90)	< 0.001	.05
SWM errors	34.19(18.39)	[0,115]	31.80(17.71)	36.32(18.20)	34.67(18.50)	39.06(19.02)	< 0.001	.02
SWM strategy	33.99(5.92)	[0,48]	33.61(5.78)	34.47(6.01)	34.05(5.94)	34.73(6.13)	< 0.001	.01

The total number includes 597 individuals with missing values on group membership.
p-values are produced based on one-way ANOVAs
Effect size: Eta-Squared for linear models

Table 21

Distribution of Dependent and Mediation Variables by Trajectory Group of Conduct Problems (unweighted data)

	Total N = 7,147	Range	1. Deteriorating N = 200	2. Early childhood limited N = 4,236	3. Improving N = 1,287	4. High risk N = 752	p-value	Effect size
Continuous variables, M (SD)								
English	2.63(1.00)	[1,5]	2.76(1.01)	2.45(0.95)	2.89(1.02)	3.16(0.99)	< 0.001	.07
Maths	2.56(1.00)	[1,5]	2.70(1.04)	2.41(0.96)	2.77(1.03)	3.01(0.97)	< 0.001	.05
Science	2.59(0.85)	[1,5]	2.71(0.91)	2.46(0.81)	2.80(0.87)	2.97(0.85)	< 0.001	.05
SWM errors	34.21(18.39)	[0,115]	34.69(17.08)	32.49(18.12)	36.68(18.84)	39.51(17.97)	< 0.001	.02
SWM strategy	33.99(5.94)	[0,48]	34.63(4.83)	33.61(6.04)	34.44(5.81)	35.13(5.67)	< 0.001	.01

The total number includes 672 individuals with missing value on group membership.
p-values are produced based on one-way ANOVAs
Effect size: Eta-Squared for linear models

Table 22

Distribution of Dependent and Mediation Variables by Trajectory Group of Hyperactivity / inattention (unweighted data)

	Total N = 7,147	Range	1. Deteriorating N = 563	2. Improving N = 951	3. Typically developing N = 4,606	4. High risk N = 430	p-value	Effect size
Continuous variables, M (SD)								
English	2.63(1.01)	[1,5]	3.04(0.97)	3.01(1.01)	2.42(0.93)	3.48(0.99)	< 0.001	.11
Maths	2.56(1.00)	[1,5]	2.95(1.02)	2.88(0.98)	2.38(0.94)	3.28(1.00)	< 0.001	.09
Science	2.59(0.85)	[1,5]	2.92(0.85)	2.86(0.86)	2.44(0.80)	3.23(0.88)	< 0.001	.09
SWM errors	34.19(18.39)	[0,115]	37.35(18.59)	37.94(17.87)	32.14(18.01)	43.83(18.40)	< 0.001	.04
SWM strategy	33.99(5.92)	[0,48]	34.36(5.79)	35.09(5.53)	33.56(6.02)	35.70(5.09)	< 0.001	.01

The total number includes 597 individuals with missing value on group membership.
p-values are produced based on one-way ANOVAs
Effect size: Eta-Squared for linear models

Table 23

Bonferroni Post-hoc Test Results: Comparison of English Average Ratings by Trajectory Group of Internalising Problems / Conduct Problems / Hyperactivity-inattention

Trajectory group	1	2	3	4
1. Internalising behaviours 'no risk'	1			
2. Internalising behaviours 'deteriorating'	0.55***	1		
3. Internalising behaviours 'low risk'	0.22***	-0.33***	1	
4. Internalising behaviours 'high risk'	0.62***	0.07	0.40***	1

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

Trajectory group	5	6	7	8
5. Conduct problems 'deteriorating'	1			
6. Conduct problems 'early childhood limited'	-0.22	1		
7. Conduct problems 'improving'	0.23	0.45***	1	
8. Conduct problems 'high risk'	0.39**	0.62***	0.17*	1

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

Trajectory group	9	10	11	12
9. Hyperactivity / inattention 'deteriorating'	1			
10.Hyperactivity / inattention 'improving'	-0.04	1		
11.Hyperactivity / inattention 'typically developing'	-0.55***	-0.51***	1	
12.Hyperactivity / inattention 'high risk'	0.55***	0.60***	1.11***	1

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

Table 24

Bonferroni Post-hoc Test Results: Comparison of Maths Average Ratings by Trajectory Group of Internalising Problems / Conduct Problems / Hyperactivity-inattention

Trajectory group	1	2	3	4
1. Internalising behaviours 'no risk'	1			
2. Internalising behaviours 'deteriorating'	0.62***	1		
3. Internalising behaviours 'low risk'	0.26***	-0.37***	1	
4. Internalising behaviours 'high risk'	0.56***	0.06	0.30***	1

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

Trajectory group	5	6	7	8
5. Conduct problems 'deteriorating'	1			
6. Conduct problems 'early childhood limited'	-0.27	1		
7. Conduct problems 'improving'	0.04	0.32***	1	
8. Conduct problems 'high risk'	0.21	0.49***	0.17	1

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

Trajectory group	9	10	11	12
9. Hyperactivity / inattention 'deteriorating'	1			
10.Hyperactivity / inattention 'improving'	-0.08	1		
11.Hyperactivity / inattention 'typically developing'	-0.49***	-0.41***	1	
12.Hyperactivity / inattention 'high risk'	0.46***	0.54***	0.95***	1

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

Table 25

Bonferroni Post-hoc Test Results: Comparison of Science Average Ratings by Trajectory Group of Internalising Problems / Conduct Problems / Hyperactivity-inattention

Trajectory group	1	2	3	4
1. Internalising behaviours 'no risk'	1			
2. Internalising behaviours 'deteriorating'	0.44***	1		
3. Internalising behaviours 'low risk'	0.18***	-0.25**	1	
4. Internalising behaviours 'high risk'	0.50***	0.06	0.31***	1

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

Trajectory group	5	6	7	8
5. Conduct problems 'deteriorating'	1			
6. Conduct problems 'early childhood limited'	-0.25	1		
7. Conduct problems 'improving'	0.07	0.31***	1	
8. Conduct problems 'high risk'	0.21	0.46***	0.14	1

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

Trajectory group	9	10	11	12
9. Hyperactivity / inattention 'deteriorating'	1			
10.Hyperactivity / inattention 'improving'	-0.02	1		
11.Hyperactivity / inattention 'typically developing'	-0.39***	-0.38***	1	
12.Hyperactivity / inattention 'high risk'	0.45***	0.47***	0.85***	1

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

5.2.2 Internalising Problems, SWM and Academic Performance

A significant regression equation4 ($p<.001$), where SWM was measured by SWM total errors, was found that explained 16% (R2) of the variance in English. Significant regression equations were also found for maths and science ($p<.001$), with an R2 of 15% and 11% respectively. When SWM was measured by strategy, all the regression equations were significant ($p<.001$), the values of R2 were 14% for English, 12% for maths, and 9% for science.

Tables 26 and 27 show the direct and indirect effects of the trajectory group membership of internalising problems on children's academic performance in, respectively, English, maths, and science at age 11, after controlling for a series of covariates including SWM as a mediator. Trajectory groups of internalising problems include the 'deteriorating' group, the 'low risk' group, the 'high risk' group, and the 'no risk' group as the reference group. SWM was measured by SWM total errors (Table 26) and SWM strategy (Table 27).

The results showed trajectory group membership of internalising problems consistently has a significant direct impact on children's performance on all three subjects (β ranges from 0.35 to 0.60, all $p<.001$). Children with an averagely lower risk of internalising behaviours, i.e., the 'no risk' group, were more likely to be rated by their teachers as higher-achieving on all three subjects than children in the 'deteriorating and the 'high risk' group. Children in the 'low risk' group tended to perform significantly poorer than children in the 'no risk' group on maths. Trajectory group membership of internalising

[4] The equation is English/maths/science = group membership of problem behaviours + age + gender + poverty + ethnicity + maternal education + maternal depression + verbal ability.

problems also showed significantly total indirect effects via SWM total errors on children's English (β = 0.06, p<.001), maths (β = 0.08, p<.001), and science (β = 0.06, p<.001) (Table 26), where SWM total errors mediated respectively 11%, 13% and 14% of the total effects[5] of trajectory group membership on English, maths, and science. However, results in Table 27 indicate SWM strategy played an insignificant role in mediating the effects of trajectory group membership on children's academic performance.

[5] Proportion of mediated total effects = indirect effects / (indirect effects + direct effects)

Table 26

Direct and Indirect Effects [unstandardised coefficients (SE) & standardised coefficients] of Internalising Problem Group Membership on Academic Performance via SWM Total Errors

Subject		Direct effects		Indirect effects	
		B (SE)	β	B (SE)	β
English	**Internalising behaviours (Ref: No risk)**	.66(.11) ***	.47***		
	Deteriorating	.32(.07) ***	.23***		
	Low risk	.07(.04)	.05		
	High risk	.26(.05) ***	.19***		
	Internalising behaviours → SWM total errors (Ref: No risk)			.08(.02) ***	.06***
	Deteriorating			.03(.01) *	.02*
	Low risk			.02(.01) *	01*
	High risk			.04 (.01) ***	.03***
Maths	**Internalising behaviours (Ref: No risk)**	.79(.12) ***	.54***		
	Deteriorating	.40(.07) ***	.27***		
	Low risk	.14(.04) **	.09**		
	High risk	.25(.05) ***	.17***		
	Internalising behaviours → SWM total errors (Ref: No risk)			.11(.03) ***	.08***
	Deteriorating			.04(.02) *	.03*
	Low risk			.02(.01) *	.01*
	High risk			.05 (.01) ***	.04***
Science	**Internalising behaviours (Ref: No risk)**	.49(.12) ***	.35***		
	Deteriorating	.25(.07) ***	.17***		
	Low risk	.06(.04)	.04		
	High risk	.19(.05) ***	.13***		
	Internalising behaviours → SWM total errors (Ref: No risk)			.08 (.02) ***	.06***
	Deteriorating			.03(.01) *	.02*
	Low risk			.02(.01) *	.01*
	High risk			.04 (.01) ***	.03***

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

Results based on regression estimates of the full model: Group membership of problem behaviours + SWM + Age + Gender + Poverty + Ethnicity + Maternal Education + Maternal Depression + Verbal Ability (Verbal Similarities at age 11)

Table 27

Direct and Indirect Effects [unstandardised coefficients (SE) & standardised coefficients] of Internalising Problem Group Membership on Academic Performance via SWM Strategy

Subject		Direct effects		Indirect effects	
		B (SE)	**β**	**B (SE)**	**β**
English	**Internalising behaviours (Ref: No risk)**	.73(.11) ***	.52***		
	Deteriorating	.35(.07) ***	.25***		
	Low risk	.09(.04) *	.06*		
	High risk	.30(.05) ***	.21***		
	Internalising behaviours → SWM strategy (Ref: No risk)			.01(.01)	.01
	Deteriorating			.01(.01)	.01
	Low risk			.002(.004)	.002
	High risk			.004(.005)	.003
Maths	**Internalising behaviours (Ref: No risk)**	.89(.12) ***	.60***		
	Deteriorating	.43(.07) ***	.29***		
	Low risk	.15(.04) ***	.10***		
	High risk	.30(.06) ***	.20***		
	Internalising behaviours → SWM strategy (Ref: No risk)			.02(.02)	.01
	Deteriorating			.01(.01)	.01
	Low risk			.003(.006)	.002
	High risk			.01(.01)	.004
Science	**Internalising behaviours (Ref: No risk)**	.56(.12) ***	.39***		
	Deteriorating	.27(.07) ***	.19***		
	Low risk	.07(.04)	.05***		
	High risk	.22(.05) ***	.16***		
	Internalising behaviours → SWM strategy (Ref: No risk)			.01(.01)	.01
	Deteriorating			.01(.01)	.01
	Low risk			.002(.004)	.002
	High risk			.004(.005)	.003

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

Results based on regression estimates of the full model: Group membership of problem behaviours + SWM + Age + Gender + Poverty + Ethnicity + Maternal Education + Maternal Depression + Verbal Ability (Verbal Similarities at age 11)

Proportion of mediated total effects = indirect effects / (indirect effects + direct effects)

5.2.3 Conduct Problems, SWM and Academic Performance

Significant regression equations were reported across the subjects ($p<.001$). When SWM was measured by total errors, the values for R2 were 16% for English, 14% for maths, and 11% for science. The values changed to 14%, 11%, and 9% respectively, when strategy was the measure for SWM.

Tables 28 and 29 show the direct and indirect effects of the trajectory group membership of conduct problems, i.e., the 'deteriorating' group, the 'improving' group, and the 'high risk' group (the 'early childhood limited' group was the reference group) on children's academic performance at age 11. Results were based on full models where SWM was measured by either SWM total errors (Table 28) or SWM strategy (Table 29).

Trajectory group membership of conduct problem had a significant impact on English at age 11 (β_1[6] = 0.33, $p<.01$; β_2[7] = 0.35, $p<.001$), maths (β_1 = 0.23, $p<.05$; β_2 = 0.25, $p < .01$), and science (β_1 = 0.26, $p<.01$; β_2 = 0.28, $p<.01$) regardless of whether SWM measured by SWM total errors (Table 28) or SWM strategy (Table 29). Children in the 'improving' group and the 'high risk' group were more likely to perform worse in teacher assessment compared to children from the 'early childhood limited' group across three subjects, whereas no significant group difference on academic performance was detected between the 'deteriorating' and the 'early childhood limited' group. Trajectory group membership showed significant indirect effects via SWM total errors on English ($\beta = 0.04$, $p<.05$), maths ($\beta = 0.06$, $p<.05$), and science ($\beta = 0.04$, $p < .05$) for children from the 'improving' and the 'high risk' groups (Table 28), where SWM total errors mediated

[6] β_1 stands for the model coefficient in the model where SWM was measured by SWM total errors
[7] β_2 stands for the model coefficient in the model where SWM was measured by SWM strategy

respectively 11%, 20% and 14% of the total effects of trajectory group membership on English, maths, and science. SWM strategy mediated respectively 6%, 11% and 8% of the total effects of trajectory group membership on English ($\beta = 0.02$, $p<.05$), maths ($\beta = 0.03$, $p<.05$), and science ($\beta = 0.02$, $p<.05$) (Table 29). While SWM total errors showed a significant mediating effect for children in the 'improving' group and the 'high risk' group, SWM strategy only played the mediator role for children in the 'high risk' group.

Table 28

Direct and Indirect Effects [unstandardised coefficients (SE) & standardised coefficients] of Conduct Problem Group Membership on Academic Performance via SWM Total Errors

Subject		Direct effects		Indirect effects	
		B (SE)	β	B (SE)	β
English	**Conduct problems**	.45(.13) **	.33**		
	(Ref: Early childhood limited)				
	Deteriorating	.02(.10)	.01		
	Improving	.24(.04) ***	.17***		
	High risk	.20(.06) ***	.14***		
	Conduct problems →SWM total errors			.06(.02) *	.04*
	(Ref: Early childhood limited)				
	Deteriorating			- .003(.02)	-.002
	Improving			.02(.01) **	.02**
	High risk			.04(.01) ***	.03***
Maths	**Conduct problems**	.34(.14) *	.23*		
	(Ref: Early childhood limited)				
	Deteriorating	.11(.10)	.07		
	Improving	.11(.05) *	.08*		
	High risk	.12(.06) *	.08*		
	Conduct problems →SWM total errors			.08(.03) *	.06*
	(Ref: Early childhood limited)				
	Deteriorating			-.004(.02)	-.003
	Improving			.03(.01) **	.02**
	High risk			.05(.01) ***	.04***
Science	**Conduct problems**	.38(.14) **	.26**		
	(Ref: Early childhood limited)				
	Deteriorating	.12(.10)	.09		
	Improving	.13(.05) **	.09**		
	High risk	.13(.06) *	.09*		
	Conduct problems →SWM total errors			.06(.02) *	.04*
	(Ref: Early childhood limited)				
	Deteriorating			-.003(.02)	-.002
	Improving			.02(.01) **	.02**
	High risk			.04(.01) ***	.03***

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

Results based on regression estimates of the full model: Group membership of problem behaviours + SWM + Age + Gender + Poverty + Ethnicity + Maternal Education + Maternal Depression + Verbal Ability (Verbal Similarities at age 11)

Proportion of mediated total effects = indirect effects / (indirect effects + direct effects)

Table 29

Direct and Indirect Effects [unstandardised coefficients (SE) & standardised coefficients] of Conduct Problem Group Membership on Academic Performance via SWM Strategy

Subject		Direct effects		Indirect effects	
		B (SE)	β	B (SE)	β
English	**Conduct problems (Ref: Early childhood limited)**	.48(.13) ***	.35***		
	Deteriorating	.01(.10)	.01		
	Improving	.25(.04) ***	.18***		
	High risk	.22(.06) ***	.16***		
	Conduct problems →► SWM strategy (Ref: Early childhood limited)			.03(.01) *	.02*
	Deteriorating			.01(.01)	.005
	Improving			.01(.004)	.004
	High risk			.02(.01) **	.01**
Maths	**Conduct problems (Ref: Early childhood limited)**	.38(.14) **	.25**		
	Deteriorating	.10(.10)	.06		
	Improving	.14(.05) **	.09**		
	High risk	.15(.06) *	.10*		
	Conduct problems →► SWM strategy (Ref: Early childhood limited)			.04(.02) *	.03*
	Deteriorating			.01(.01)	.01
	Improving			.01(.01)	.01
	High risk			.03(.01) **	.02**
Science	**Conduct problems (Ref: Early childhood limited)**	.40(.14) **	.28**		
	Deteriorating	.11(.10)	.08		
	Improving	.14(.05) **	.10**		
	High risk	.15(.06) *	.11*		
	Conduct problems →► SWM strategy (Ref: Early childhood limited)			.03(.01) *	.02*
	Deteriorating			.01(.01)	.01
	Improving			.01(.005)	.004
	High risk			.02(.01) **	.01**

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

Results based on regression estimates of the full model: Group membership of problem behaviours + SWM + Age + Gender + Poverty + Ethnicity + Maternal Education + Maternal Depression + Verbal Ability (Verbal Similarities at age 11)

Proportion of mediated total effects = indirect effects / (indirect effects + direct effects)

5.2.4 Hyperactivity / inattention, SWM and Academic Performance

Significant regression equations were reported across the subjects ($p<.001$). When SWM was measured by total errors, the values for R2 were 16% for English, 15% for maths, and 11% for science. The values changed to 15%, 12%, and 10% respectively, when SWM was measured by strategy. Tables 30 and 31 display the direct and indirect effects of the trajectory group membership of hyperactivity / inattention on children's academic performance. Table 30 shows the results with total errors as the mediator. SWM strategy is the mediator in Table 31.

Model results showed significant direct effects of hyperactivity / inattention trajectory group membership on children's academic performance across subject and across trajectory group (β ranges from 0.56 to 0.88, $p < .01$). Children in the group with higher risk of hyperactivity / inattention behaviours were more likely to have poorer teacher-reported performance. Trajectory group membership showed significant indirect effects via total errors on children's English ($\beta = 0.11$, $p < .001$), maths ($\beta = 0.15$, $p < .001$), and science ($\beta = 0.11$, $p < .001$) for all groups (Table 30), and total errors mediated respectively 13%, 19% and 17% of the total effects of trajectory group membership on English, maths, and science. Strategy mediated less of the total effects, 4% for English, 6% for maths and 6% for science; such mediating effects were only found in children from the 'improving' and the 'high risk' group. Significant indirect effects of SWM strategy were found on children's English ($\beta = 0.04$, $p<.001$), maths ($\beta = 0.05$, $p<.001$), and science ($\beta = 0.04$, $p<.001$) (Table 31).

Table 30

Direct and Indirect Effects [unstandardised coefficients (SE) & standardised coefficients] of Hyperactivity / inattention Group Membership on Academic Performance via SWM Total Errors

Subject		Direct effects		Indirect effects	
		B (SE)	**β**	**B (SE)**	**β**
English	**Hyperactivity / inattention (Ref: Typically developing)**	1.12(.12) ***	.80***		
	Deteriorating	.30(.06) ***	.22***		
	Improving	.23(.05) ***	.16***		
	High risk	.59(.07) ***	.42***		
	Hyperactivity / inattention► SWM total errors (Ref: Typically developing)			.16(.02) ***	.11***
	Deteriorating			.04(.01) **	.03**
	Improving			.03(.01) ***	.02***
	High risk			.09 (.01) ***	.06***
Maths	**Hyperactivity / inattention (Ref: Typically developing)**	.98(.13) ***	67***		
	Deteriorating	.27(.06) ***	.18***		
	Improving	.18(.05) **	.12**		
	High risk	.53(.08) ***	.36***		
	Hyperactivity / inattention► SWM total errors (Ref: Typically developing)			.23(.03) ***	.15***
	Deteriorating			.05(.01) ***	.03***
	Improving			.05 (.01) ***	.03***
	High risk			.13 (.02) ***	.09***
Science	**Hyperactivity / inattention (Ref: Typically developing)**	.81(.13) ***	.56***		
	Deteriorating	.20(.06) **	.14**		
	Improving	.16 (.05) **	.11**		
	High risk	.45 (.07) ***	.31***		
	Hyperactivity / inattention► SWM total errors (Ref: Typically developing)			.16(.02) ***	.11***
	Deteriorating			.04(.01) **	.03**
	Improving			.03(.01) ***	.02***
	High risk			.09(.01) ***	.06***

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

Results based on regression estimates of the full model: Group membership of problem behaviours + SWM + Age + Gender + Poverty + Ethnicity + Maternal Education + Maternal Depression + Verbal Ability (Verbal Similarities at age 11)

Proportion of mediated total effects = indirect effects / (indirect effects + direct effects)

Table 31

Direct and Indirect Effects [unstandardised coefficients (SE) & standardised coefficients] of Hyperactivity / inattention Group Membership on Academic Performance via SWM Strategy

Subject		Direct effects		Indirect effects	
		B (SE)	β	B (SE)	β
English	**Hyperactivity / inattention (Ref: Typically developing)**	1.23(.12) ***	.88***		
	Deteriorating	.33(.06) ***	.24***		
	Improving	.25(.05) ***	.18***		
	High risk	.65(.07) ***	.47***		
	Hyperactivity / inattention → SWM strategy (Ref: Typically developing)			.05(.01) ***	.04***
	Deteriorating			.01(.01)	.004
	Improving			.02(.005) **	.01**
	High risk			.03(.01) ***	.02***
Maths	**Hyperactivity / inattention (Ref: Typically developing)**	1.13(.13) ***	.77***		
	Deteriorating	.31(.07) ***	.21***		
	Improving	.20(.05) ***	.13***		
	High risk	.62(.08) ***	.42***		
	Hyperactivity / inattention → SWM strategy (Ref: Typically developing)			.08(.02) ***	.05***
	Deteriorating			.01(.01)	.01
	Improving			.03(.01) ***	.02***
	High risk			.04(.01) ***	.03***
Science	**Hyperactivity / inattention (Ref: Typically developing)**	.91(.13) ***	.64***		
	Deteriorating	.23(.06) ***	.16***		
	Improving	.17(.05) **	.12**		
	High risk	.51(.07) ***	.36***		
	Hyperactivity / inattention → SWM strategy (Ref: Typically developing)			.06(.01) ***	.04***
	Deteriorating			.01(.01)	.005
	Improving			.02(.01) ***	.01***
	High risk			.03(.01) ***	.02***

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

Results based on regression estimates of the full model: Group membership of problem behaviours + SWM + Age + Gender + Poverty + Ethnicity + Maternal Education + Maternal Depression + Verbal Ability (Verbal Similarities at age 11)

Proportion of mediated total effects = indirect effects / (indirect effects + direct effects)

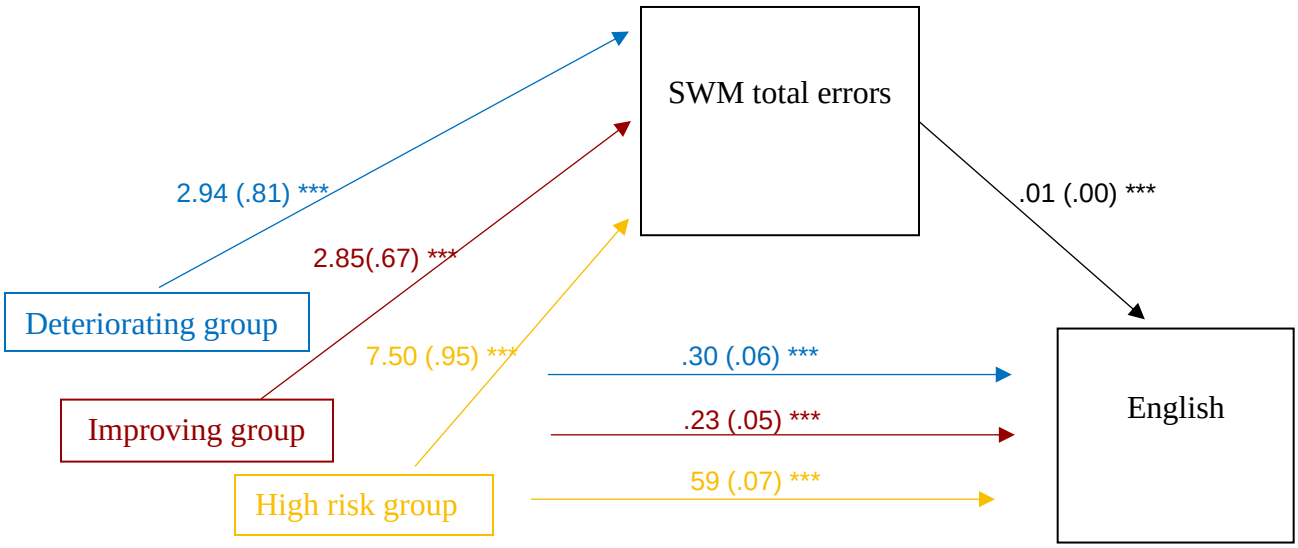
5.3 Summary of Mediation Analysis Results

Given higher levels of child psychopathology symptoms were associated with poorer academic performance in general and by subject (Ende et al., 2016; Wickersham et al., 2021), the present study conducted a mediation analysis to explore the role of SWM as a the possible underlying mechanism for effects of child psychopathology trajectory group on children's academic performance in English, maths, and science. More specifically, the mediation analysis investigated whether SWM measured by SWM total errors or SWM strategy explained group differences in academic performance. The results showed that **SWM total errors** acted as a mediator that explained the trajectory group membership effects on academic performance across three child psychopathology domains. However, it was not a significant mediator for children in the 'deteriorating' group of conduct problem (Table 27), which is consistent with the previous regression modelling results those children from the 'deteriorating' group of conduct problem showed no difference to children from the 'early childhood limited' group in term of total errors. The results indicated **SWM strategy** was not a mediator for the impact of internalising problems trajectory group membership on academic performance (Table 26), as expected according to the previous finding that children's SWM skills measured by strategy do not differ between the 'no risk' group and any of other internalizing problems trajectory groups. However, SWM strategy was a mediator in the conduct problem – academic performance in English, maths, and science pathways but only for children in the 'high risk' group (Table 28); it was also a mediator in the hyperactivity / inattention – academic performance in English, maths, and science pathways but only for children from the 'improving' and 'high risk' groups (Table 30).

Given that SWM total errors and SWM strategy tended to show mediating effects more consistently between hyperactivity / inattention trajectory group membership and academic performance, the present study illustrated the direct effects of hyperactivity / inattention trajectory groups and their indirect effects via SWM using figures (Figures 9 to 14). The figures indicate the ‘high risk’ group consistently showed the poorest SWM performance measured by both SWM total errors and SWM strategy, and the lowest level of teacher-reported academic performance across three subjects.

Figure 9

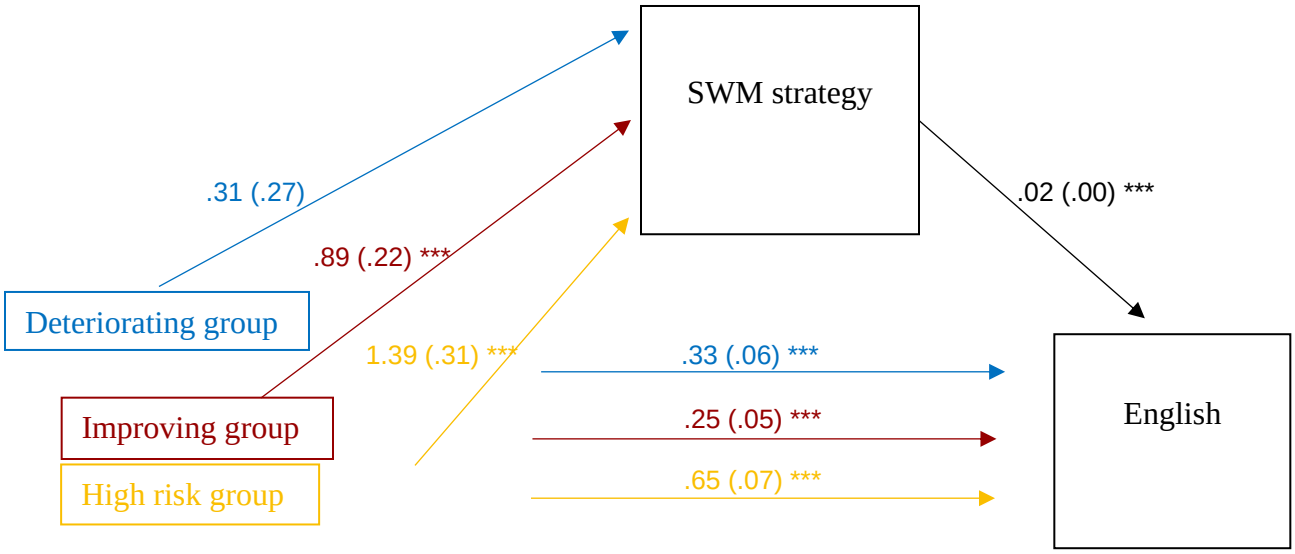
Direct and Indirect Effects of Trajectory Group Membership of Hyperactivity / inattention on English via SWM Total Errors



Note. ***p<0.001. Typically developing group is the reference group.

Figure 10

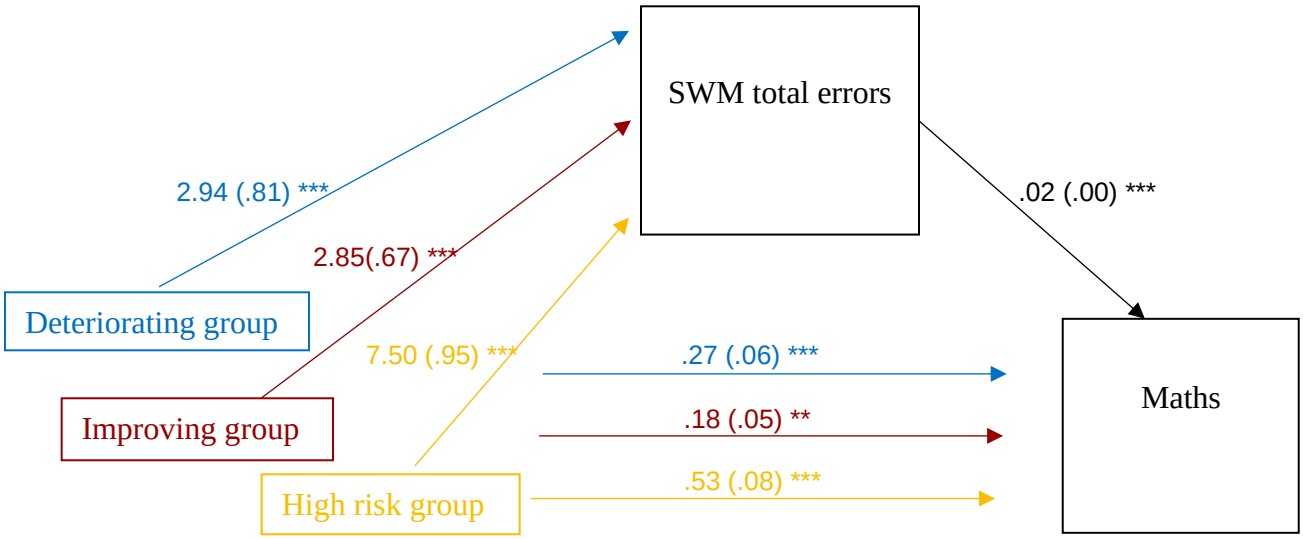
Direct and Indirect Effects of Trajectory Group Membership of Hyperactivity / inattention on English via SWM Strategy



Note. ***p<0.001. Typically developing group is the reference group.

Figure 11

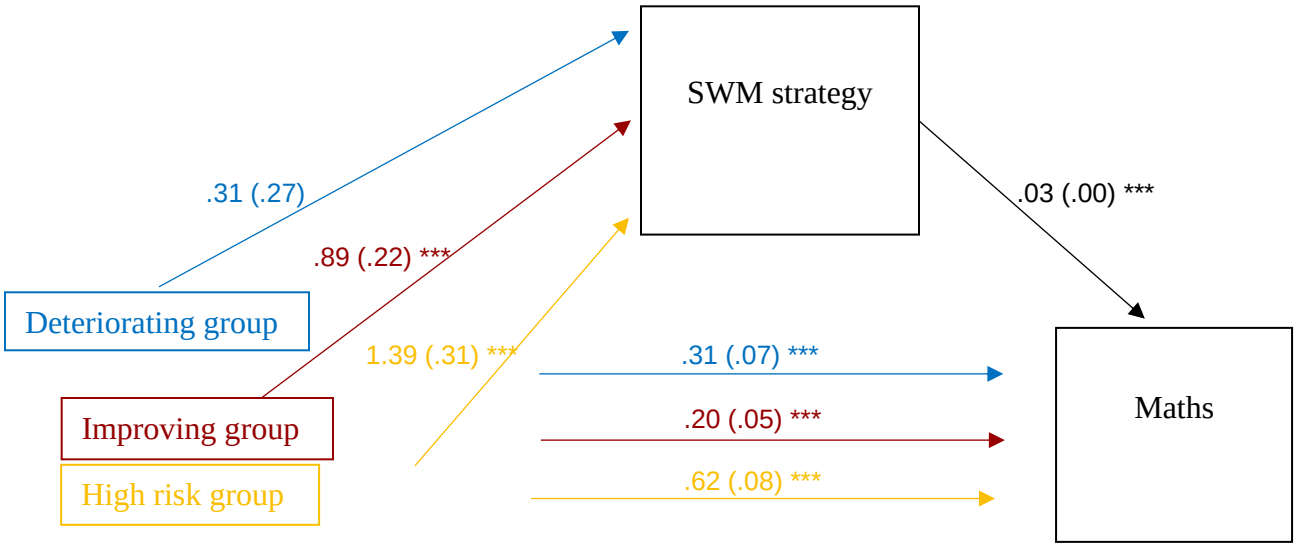
Direct and Indirect Effects of Trajectory Group Membership of Hyperactivity / inattention on Maths via SWM Total Errors



Note. ***p<0.001, **p<0.01. Typically developing group is the reference group.

Figure 12

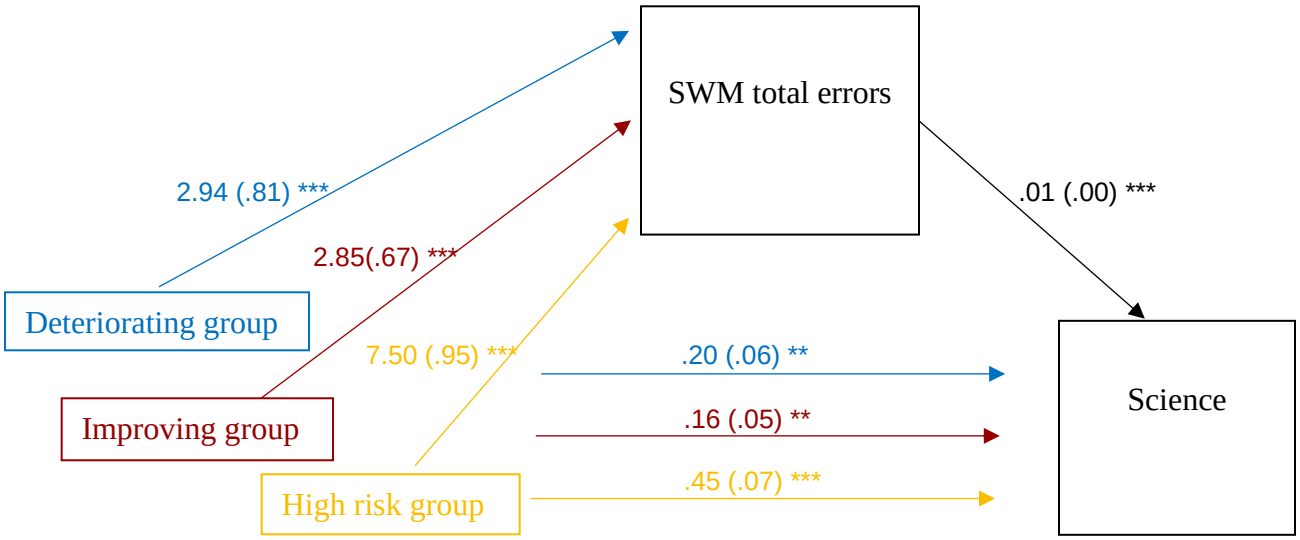
Direct and Indirect Effects of Trajectory Group Membership of Hyperactivity / inattention on Maths via SWM Strategy



Note. ***p<0.001. Typically developing group is the reference group.

Figure 13

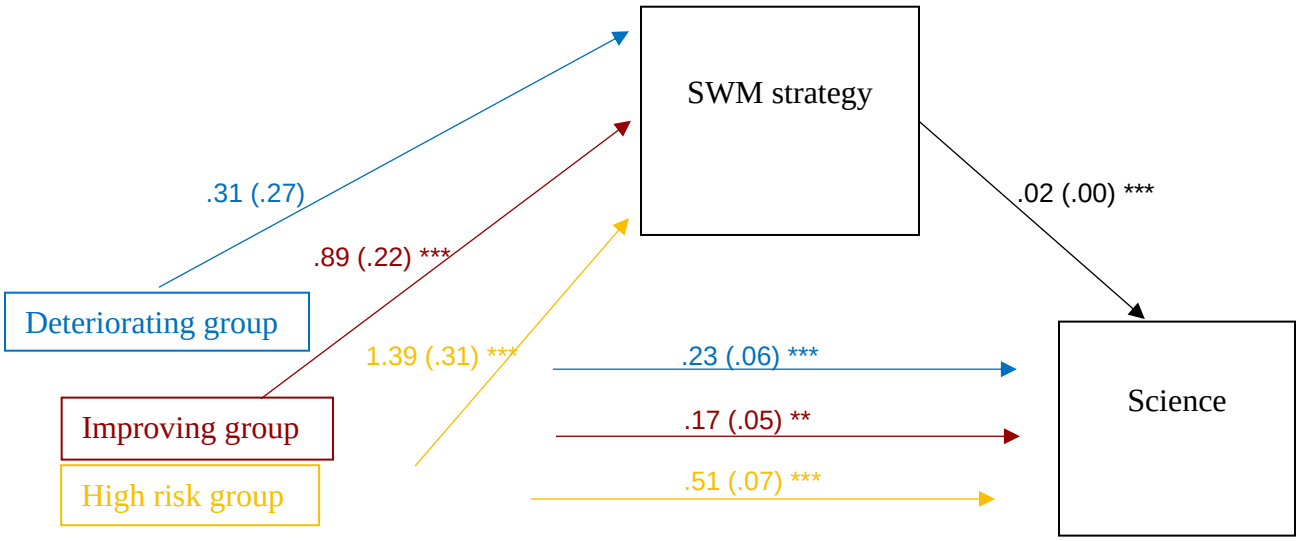
Direct and Indirect Effects of Trajectory Group Membership of Hyperactivity / inattention on Science via SWM Total Errors



Note. ***p<0.001, **p<0.01. Typically developing group is the reference group.

Figure 14

Direct and Indirect Effects of Trajectory Group Membership of Hyperactivity / inattention on Science via SWM Strategy



Note. ***p<0.001, **p<0.01. Typically developing group is the reference group.

Chapter 6

Exploring Views of Educational Psychology Professionals: What Are the Implications of the Link between Child Psychopathology and Spatial Working Memory

6.1 Background

Chapter 4 of the present study depicted a link between child psychopathology and SWM: the development of children's internalising behaviours, conduct problems, and hyperactivity / inattention from age 3 to age 11 was associated with their SWM skills at age 11, and poorer SWM skills measured at age 11 were most consistently found in children at risk of chronically high levels of child psychopathology symptoms. Educational psychology professionals (including Educational Psychologists, Trainee Educational Psychologists, Child and Adolescent Psychologists, and Assistant Educational Psychologists) provide support for children with special educational needs and disabilities (SEND). The present study attempts to explore educational psychology professionals' views around the child psychopathology-SWM link. These views were of interest in this study, because, given the professional background of the author (i.e., trainee educational psychologist) and the fact that individuals each have unique ways of interpreting the surrounding world, gaining educational psychology professionals' views about the link (e.g., how they perceive the credibility of the link; the implications for their work) could, firstly, deepen our understanding of the child psychopathology-SWM link; secondly, inform practice, e.g., whether further trainings are needed among educational psychology professionals to increase the awareness about the link; supporting children's SWM

functioning by considering their behavioural / emotional needs. However, little is known regarding educational psychology professionals' views about the link.

6.1.1 Personal Construct Psychology

The online survey of the current study adopted the theory of Personal Construct Psychology (Kelly, 1955, 1991) as a framework to conceptualise relevant concepts including views, beliefs, and experiences. According to Personal Construct Psychology, individuals' views about the surrounding world are reflections of their beliefs, and beliefs are core personal values shaped by one's experiences.

The Personal Construct Psychology (PCP) theory has originated from George Kelly's (Kelly, 1955, 1991) work of developing a new theory of personality. Kelly (1955) claims that PCP theory follows constructive alternativism, a philosophical view of his. In essence, constructive alternativism suggests that, firstly, individuals' perceptions and understandings of reality are not static; secondly, individuals can choose alternative ways to understand the surrounding world. Therefore, individuals can be viewed as scientists and adventurers; they are able to find from their experiences the alternative interpretations and experiment with new interpretations to improve their systems of understanding the world (Fransella, 1995; Walker & Winter, 2007).

The PCP theory created a psychological concept; namely, the personal construct (Bannister & Fransella, 1986). The theory explains that individuals access the world through constructs, which are schemes or templates they created to predict a sequence of events in real life. It is essential to note that all constructs are assumed to be bipolar in PCP (Fransella, 1995). People notice similarities as well as contrasts in perceived objects or experienced events (Walker & Winter, 2007). With a similarity and the corresponding

opposite, one can create a personal dichotomous construct (Kelly, 1955). It is important to note that, although two poles of one construct are usually negatively correlated, the correlation may not be as strictly dichotomous as Kelly describes ((Walker & Winter, 2007). Meanwhile, bipolar constructs can be understood as scales where people position themselves regarding different circumstances (Kelly, 1955).

6.1.2 Beliefs, Views, and Experiences

PCP suggests that personal constructs are derived from past experiences (Kelly, 1955). It is individuals' interpretation of their experiences that make their constructs unique and personal. Personal constructs are hierarchically organized within construction systems. In a construction system, one construct may subsume or be subsumed by other constructs and is respectively recognized as superordinate construct and subordinate construct. (Beaver, 2011, p. 83) clarified that constructs develop from lower-level "behaviourally specific discriminatory constructs" to higher-level "more generally descriptive discriminatory constructs, with attributed values". The constructs at a higher level are core constructs that serve to shape one's sense of self, maintain one's identity, and are fundamental to other lower-level constructs; preferred poles of the core constructs usually reflect individuals' beliefs and values (Beaver, 2011). It seems difficult to develop a clear picture of one construction system because of its complex pattern. However, the ordinal relationship made it possible to unearth other constructs when we know one construct in the construction system.

6.1.3 The Present Survey Study

In summary, this study considered educational professionals' views or perceptions as subordinate constructs of their beliefs, which are higher-level constructs. Nevertheless, both emerge from educational professionals' experiences. Therefore, this part of the thesis used the online survey to explore three research questions as follows:

1. What are educational psychology professionals' perceptions of the credibility of the child psychopathology-SWM link?
2. Does their view on the credibility of such a link correlate with their relevant experiences and self-perception of competence[8]?
3. What are their views around the impact of such a link on their practice?

6.2 Methodology

6.2.1 Sampling

An anonymous online survey method was adopted to gather educational psychology professionals' views. Anyone who considers themselves to be professionals working in the field of educational psychology could participate. The survey was created using Qualtrics, a cloud-based platform for creating and distributing surveys. The survey was modified according to the feedback from one Educational Psychologist and three Trainee Educational Psychologists. The final version of the survey (Appendix 1) was distributed to educational psychology professionals via Twitter, EPNET[9] and to a class of

[8] Self-perception of competence is regarded as a subjective form of one's professional experiences.
[9] EPNET is an online open and public forum for the exchange of ideas and information for those working within the field of educational psychology.

third-year Trainee Educational Psychologists (TEPs) via social media on 28th January 2021. The survey was also distributed to TEPs and Educational Psychologists (EPs) working with a local authority educational psychology service on 17th February 2021.

In total, 49 participants responded to the survey as of 28th March 2021. Eight responses (16% of the sample) were incomplete, including one participant who declined to proceed to the survey. Supplementary Table 1 in Appendix 2 shows survey response rates for each multiple-choice question.

6.2.2 The Survey and Measures

The survey consists of three blocks of questions. The first block, 'Background Information', collected information around participants' current and previous occupations. The second block, 'Experience and Self-perception of Competence', asked participants to give ratings about their professional experiences / competence working with children with internalising behaviours, externalising behaviours, and poor SWM. The third block of the survey, 'Implications for Educational Psychology Practice', using open questions, encouraged participants to share their views about the link between child psychopathology symptoms and SWM, and the possible implications of such a link for their work.

There were five measures for participants' professional experiences. Firstly, ***years of practice***, participants were asked '*how many years have you been practising within the field of educational psychology*', and they were given four options, i.e., '*less than 3 years*, '*3 – 5 years*', '*5 – 10 years*', and '*more than 10 years*'. Secondly, a 3-point scale, i.e., '*rarely*', '*sometimes*', '*quite often*' was used to measure ***how often participants work with children and young people with internalising behaviours***. The same 3-point scale was used to obtain participants' responses for, respectively, their ***frequency of working with***

externalising behaviours, and ***poor SWM***. Higher ratings indicate more relevant professional experiences. ***Self-perception of competence***, a subjective form of one's professional experiences, was measured by a 4-level scale based on the four stages of competence (i.e., '*unconscious incompetence'*; '*conscious incompetence'*; '*conscious competence*'; '*unconscious competence*'). Participants were asked to rate their competence in working with children and young people with, respectively, internalising behaviours, externalising behaviours, and poor spatial working memory. Higher ratings indicate more self-confidence in relevant competence and knowledge.

A 5-point scale question captured educational professionals' ***views about the credibility of the child psychopathology-SWM link*** (from '*extremely unbelievable*' to *'extremely believable*'). A higher rating presents a higher level of credibility from the participants' perspective. Participants were also given an option of '*I am not sure*', which was coded as a user missing value for correlation analysis.

6.2.3 Analytic Strategy

The survey provided the present study with both quantitative and qualitative data. SPSS 26.0 was used to analyse the quantitative data. The percentages of the participants who reported the child psychopathology-SWM link as '*extremely unbelievable*', *'somewhat unbelievable', 'neither believable nor unbelievable, 'somewhat believable'* or *'extremely believable*' were presented to illustrate participants' views about the credibility of the link. For the second research question of the online survey, ANOVA was used to investigate the relationship between the view of the credibility of the link and years of practice. Correlational analysis was used to investigate the relationship between view of the link and participant-reported experiences (i.e., frequency; self-perception of

competence) working with children and young people with, respectively, internalising behaviours, externalising behaviours, and poor SWM skills. For the third research question, participants' answers to the open questions around impact for their practice were analysed using thematic analysis (Clarke et al., 2015). Clarke et al. (2015, p. 228) summarised that thematic analysis uses coding to search for repeated patterns, namely themes, across different pieces of data; it helps investigate "experiential questions" about people's experiences, perspectives, and their construction of reality. The qualitative data analysis generally followed the six phases of thematic analysis suggested by Braun and Clarke (2006) and illustrated by Clarke et al. (2015). The generation of initial codes was done manually. All the codes were then organised into groups to form candidate themes which were subsequently reviewed, refined and / or defined, via discussion with the author's supervisor, to form meaningful final themes (Appendix 3).

6.3 Results

6.3.1 Professional Profile of the Participants

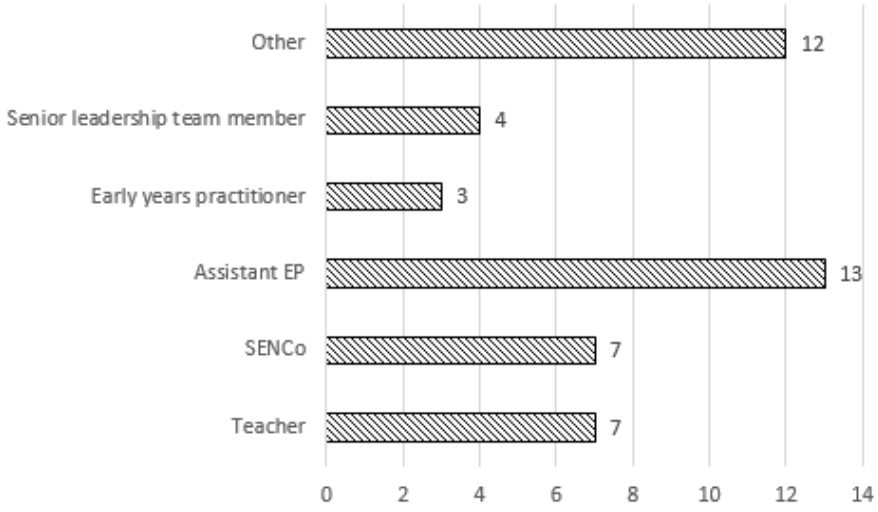
Nineteen TEPs (40% of the sample), 20 Main Grade EPs (41%), Five Senior EP (10%), One Principal EP (2%), One Assistant EP (2%), and two independent EP (4%) submitted the survey, 18 of whom (37%) indicated experiences of less than 3 years working in the field of educational psychology. Six professionals (12%) have 3 – 5 years of experiences. Another six reported having 5 – 10 years of experiences. The remaining 18 professionals (37%) have been working in the field for more than 10 years.

Figure 15 presents participants' previous role(s) (N = 48). The category of 'Other' showed some participants had worked in a range of relatively similar or associated roles,

such as Education Health and Care Plan Coordinator, Tutor in alternative provision, Assistant Special Educational Needs Co-ordinator, and University Lecturer.

Figure 15

Participants' Previous Roles



6.3.2 Participants' View about the Credibility of the Child Psychopathology-SWM Link

Four participants reported the link was '*somewhat unbelievable*' (9.8%), another four found the association '*neither believable nor unbelievable*' (9.8%). Twenty-two participants chose '*somewhat believable*' (53.7%), and five participants rated the association as '*extremely believable*' (12.2%). Six participants chose '*I am not sure*' (14.6%).

6.3.3 Professional Experiences and View about Credibility of the Child Psychopathology-SWM Link

Professional experiences were measured by the length of years of practice (a categorical variable), self-rated frequency working with children and young people with

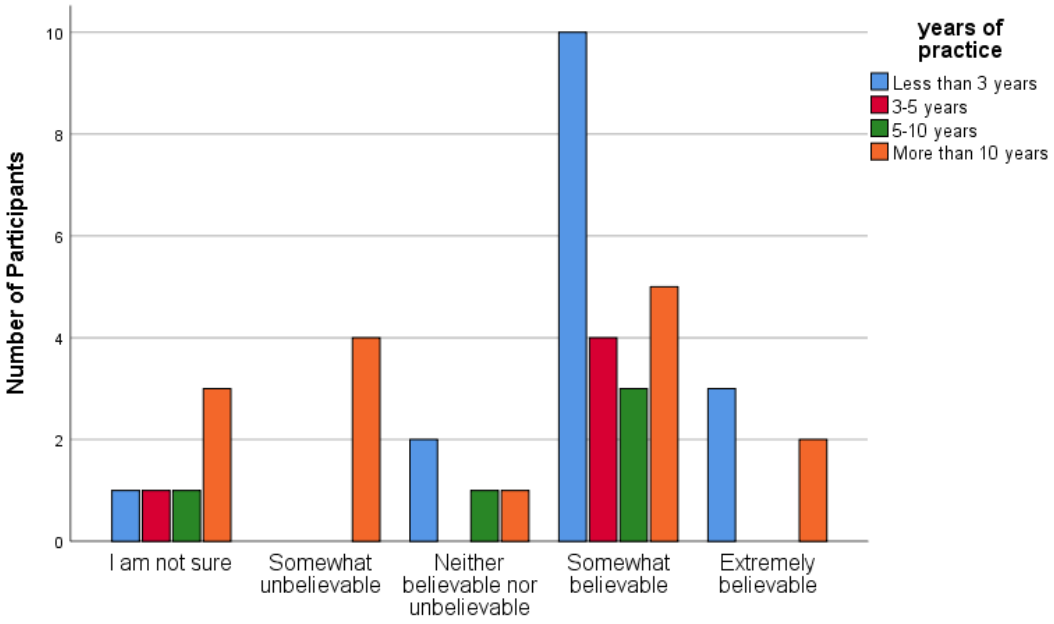
internalising behaviours / externalising behaviours / poor SWM skills (continuous variables), and self-perception of competence.

Years of Practice

Figure 16 illustrates that participants tended to report the association is somewhat believable across the four groups of different lengths of practice years.

Figure 16

Participants' View around the Credibility of the Child Psychopathology-SWM Link by Group of Lengths of Practice Years



Note, Less than 3 years (N=16), 3-5 years (N=5), 5-10 years (N=5), More than 10 years (N=15).

One-way between-subject ANOVA was adopted to explore whether participants' view about the association differs according to the length of years of practice. For one-way ANOVA, it is important that each group contains at least six subjects (Yeager, 2021). Given that participants from the '3-5 years' group and '5-10 years' group gave similar responses (Figure 16), the present study combined these two groups to make the '3-10 years' group where participants worked for 3-10 years within the field of educational

psychology. As a result, participants were grouped into three different groups according to their years of practice. Results of the Kolmogorov-Smirnov Test of normality showed non-normal distribution across all three groups, D (15) = 0.35, p < .001; D (8) = 0.51, p < .001; D- (12) = 0.28, p < .05. Levene's tests were used to test the homogeneity of variance where the view of the link's credibility was the outcome variable and years of practice was the factor. Results showed that for views around the association's credibility, the variance was significantly different in the three groups, F (2, 32) = 10.62, p < .001. As a result, the non-parametric alternative to one-way ANOVA, i.e., the Jonckheere–Terpstra test was adopted (Bewick et al., 2004). The test result showed that, for participants' views about the link's credibility, there is no significant difference among any pair of the three groups (p = .10), suggesting participants belief around the child psychopathology-SWM link was not related to the length of their years of practice.

Frequency working with children and young people with internalising behaviours / externalising behaviours / poor SWM skills

The Kolmogorov-Smirnov Test of normality results indicated frequency working with internalising behaviours [D (35) = 0.40, P < .001], frequency working with externalising behaviours [D (35) = 0.50, P < .001], frequency working with poor SWM [D (35) = 0.33, P < .001], and view about credibility of the link [D (35) = 0.37, P < .001] were all significantly non-normal. Therefore, the non-parametric test of correlational analysis i.e., Spearman's test was used (Table 32).

Table 32 shows a significant relationship between the frequency of working with children and young people with externalising behaviours and participants' belief about the link, and the strength of the relationship is moderate (r = .41, p < .001). Participants'

experiences working with externalising behaviours were also positively correlated with their experiences of internalising behaviours ($r = .46$, $p < .001$). However, participants' views on the association's credibility showed no significant relationship with their experiences working with internalising behaviours ($r = .16$, ns) or poor SWM ($r = .23$, ns). The results suggested participants tended to be more convinced by the link when they indicated they have more frequent experiences working with cases of externalising behaviours.

Self-perception of Competence

The Kolmogorov-Smirnov Test of normality results showed self-perception of competence in working with internalising behaviours [$D (35) = 0.37$, $P < .001$], self-perception of competence in working with externalising behaviours [$D (35) = 0.31$, $P < .001$], self-perception of competence in working with poor SWM [$D (35) = 0.32$, $P < .001$], and view about the credibility of the association [$D (35) = 0.37$, $P < .001$] were all significantly non-normally distributed. Therefore, non-parametric test of correlational analysis i.e., Spearman's test was used (Table 32).

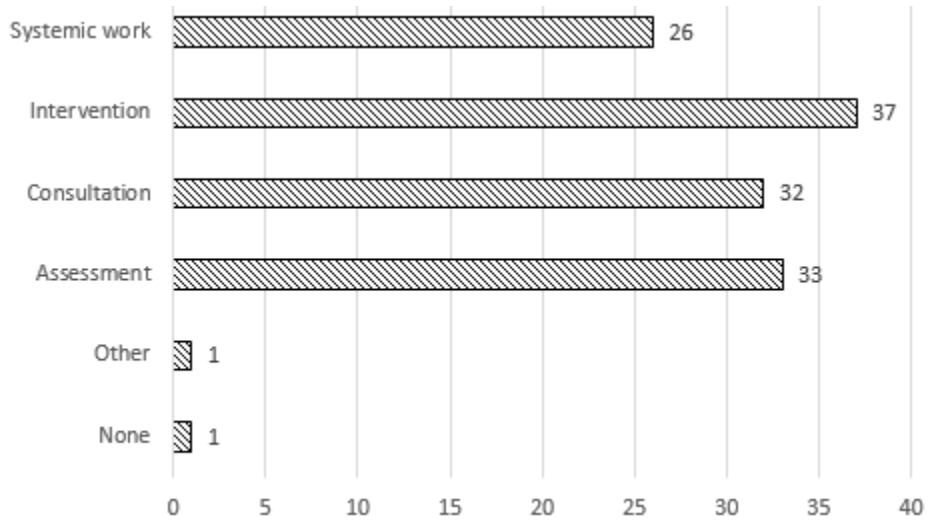
Table 32 indicates that participants' self-perception of competence in working with internalising behaviours / externalising behaviours / poor SWM did not affect the extent to which they believe the child psychopathology-SWM association. Participants who were more confident about their competence in working with internalising behaviours were also likely to report a higher level of confidence in working with externalising behaviour cases ($r = .75$, $p < .001$). There was a significant negative relationship between experiences in terms of frequency working with poor SWM cases and self-perception of competence in working with internalising behaviour cases ($r = -.32$, $p < .05$).

6.3.4 Impact of the Child Psychopathology-SWM Link on Educational Psychology Practice

As shown in Figure 17, most of the participants reported the association has implications for their practice in areas including intervention (92.5% of the participants who gave valid responses), assessment (82.5%), consultation (80%). 65% of them also recognized such association could affect systemic work. One participant chose '*other*' and specified "*Formulation*" (2.5%). One participant (2.5%) responded that none of the areas would be affected.

Figure 17

Which Area(s) of Educational Psychology Practice Can be Affected by the Association: Responses from Professionals



Note, in total, 40 participants gave valid responses.

Participants were asked to share their thoughts and explain how the area(s) (as illustrated in Figure 17) they chose could be impacted by the link between a higher risk of consistently chronic levels of child psychopathology and poorer SWM. The following

themes regarding the impact of such link on professional practice emerged from participants' comments:

Interventions / Provisions

Most participants reported that this link could support informing specific interventions / provisions. Given that the direction of the link remains unclear, some participants mentioned they might consider interventions focusing on supporting the development of SWM where appropriate following assessment. For example, an EP suggested, "to look at ways children can be taught strategies to support their spatial skills." A TEP reported identifying "appropriate intervention that could help support spatial ability." Some participants tend to put more emphasis on meeting children's needs underlying their internalising / externalising behaviours. A TEP suggested "teaching styles would need to be altered to cater for 'chronic' levels"; another TEP noted, "broaden intervention offer with internalising / externalising behavioural difficulties." At the same time, some other participants suggested interventions / strategies considering children's cognitive as well as social emotional mental health needs. An EP wrote that "perhaps working on more physical, kinaesthetic tasks as well as interventions targeted at emotional literacy." Another EP suggested, "multi-modal intervention focusing on emotional, behavioural needs plus elements from the neuro-sequential model to respond to early neurological disruption."

Hypothesis Formulation

This link could guide hypothesis formulation. A Principal Educational Psychologist commented, "a better understanding of this link might help us to generate hypotheses and offer possible new understandings of a child's presentation", which is explained further by an EP that "it would be filed, cross referenced, tested against what I know and what I don't

know, and we would come to a formulation whereupon we might say something like: this might be why you and we could try this to……"

Assessment

This link could affect assessment work. Several participants indicated that considering the link, they are likely to assess SWM skills "more often", "more thorough" or put more "focus" on assessment of SWM, especially when working with children and young people with internalising and /or externalising behaviours. Some participants shared their reflections on relevant assessment tools. For instance, an independent EP mentioned "detailed early relational and experiential history (will be) needed from caregivers", and another EP noted "(we will) Need more accurate measures of Spatial WM".

Consultation and Systemic Work

Participants consider raising clients' awareness of the link via consultation and systemic work. Some participants recognised that the link "can help those involved view the child differently" and that "it would be useful information to bring to consultation and discuss with parents and teachers." It was also mentioned by several participants that relevant information could be shared with "parents and teachers" and "schools" via "training".

Reflections – Linking to Existing Knowledge

Some participants described how this link is in line with some of their existing knowledge. A TEP wrote, "I have never considered this as a direct link, although I recognise more generally the connection between academic or cognitive difficulties and internalising and externalising behaviours." An EP mentioned, "we already consider that children with emotional or behavioural difficulties may not have the cognitive capacity left to focus on learning." Some other participants related "chronically high levels of" child

psychopathology – one side of this link – to “trauma” and its impact on cognitive development.

Reflections – Future Research

More research is required for understanding the direction of the link and its underlying mechanisms. One EP noted that the link is “interesting”, and he / she is “wondering about directionality and causality.” Similarly, a TEP shared that “it's an interesting link to think about, although without further explanation for why this would be, I would currently be inclined to see this as correlation rather than causation.” A Principle Educational Psychologist considered the link with caution - “a correlation alone isn't going to change EP practice - we'd need to know that this is more than a statistical artefact (common in large scale studies).”

6.4 Summary of Survey Results

The analysis of the survey data revealed most survey respondents, to some extent, believe that there is a link between high levels of child psychopathology symptoms and poor SWM skills. Participants showed mixed responses. For example, some were surprised by the link, some reported their experiences resonate with the fining. Participants who have more frequently worked with children or young people with externalising behaviours are more likely to consider this link as believable. Participants suggested this link could affect different areas of their professional practice, e.g., intervention, hypothesis formulation, and assessment; it would be useful in understanding children and young people’s behavioural presentations or cross-referring to some existing knowledge around cognitive functioning and trauma. However, some participants also emphasized that further research is needed to understand the direction of the link and its underlying mechanisms.

Table 32

Spearman's Correlation Coefficient and Descriptive Statistics of Professional Experiences, Self-perception of Competence and View about Credibility of Child Psychopathology-SWM Association

	N	*M*	*SD*	1	2	3	4	5	6	7
1. View about the credibility of the association	35	3.80	0.83	1.00						
2. Experience of internalising behaviours	41	2.68	0.47	0.16	1.00					
3. Experience of externalising behaviours	41	2.85	0.36	0.41*	0.46*	1.00				
4. Experience of SWM	41	2.27	0.59	0.23	0.11	0.06	1.00			
5. Self-perception of competence in internalising behaviours	41	2.88	0.60	-0.03	0.06	0.08	-0.32*	1.00		
6. Self-perception of competence in externalising behaviours	41	2.90	0.66	-0.03	0.09	0.09	-0.15	0.75**	1.00	
7. Self-perception of competence in SWM	41	2.32	0.65	0.32	-0.17	-0.04	0.11	0.29	0.12	1.00

Note: *p<0.05 **p<0.01; the value range for variable 1 is [1, 5], the value range for 2, 3, and 4 is [1, 3], the value range for 5, 6, and 7 is [1, 4].

Chapter 7

Discussion

The present study, using data from a large general-population longitudinal sample, 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. The present study also conducted a mediation analysis to reveal whether children differ in their academic performance across different trajectories groups as a result of SWM differences. The views of professionals working in the field of educational psychology were sought using an anonymous online survey regarding the link between child psychopathology symptoms and SWM and its implications for the educational psychology practice.

7.1 Trajectory Groups of Children's Internalising Problems, Conduct Problems and Hyperactivity / inattention

The present study found four trajectory groups for each symptom domain from age 3 to 11, consistently with some previous studies (e.g., Fanti, 2010; Flouri et al., 2018; Gutman et al., 2019). The age span seems to play a role in the emerging number of trajectory groups of child psychopathology symptoms. For example, Korhonen et al. (2018) followed participants from ages 4 or 5 to ages 26 or 27 and reported three groups for internalising problems; it is likely that the two groups with averagely moderate-level

internalising problems identified by the present study were regarded as one group by Korhonen et al. (2018) due to a broader age span. Franke et al. (2018) proposed there are five trajectory groups for the development of ADHD from age 4 to 40, including one group which showed ADHD onset in adulthood – an atypical group that can only be detected by studies that track subjects' ADHD symptoms from childhood to adulthood, beyond the age scope of the present study. Therefore, children tend to follow one of four internalising problems / conduct problems / hyperactivity-inattention trajectories from early childhood to early adolescence.

Most children follow a typically developing trajectory or a trajectory of relatively less concern. Around 72% of the studied child population belonged to the 'no risk' or 'low risk' group of internalising problems, where none of the children or a small proportion within the group was at risk of internalising problems. 82.6% of the participants were assigned to the 'early childhood limited' or 'improving' group of conduct problems – they were more likely to present with conduct problems between age 3 and 5, but the proportion of children at risk of conduct problems in the two groups decreased to none or less than 30% after the age of 5. In terms of hyperactivity / inattention, 62.7% of the children were rarely at risk from age 3 to 11 (the 'typically developing' group), and another 19.4% showed a steadily decreased probability of risk (the 'improving' group).

A relatively small number of children were assigned to the 'deteriorating' group for each child psychopathology domain. Group sizes were 10% for internalising problems, 5.6% for conduct problems, and 11.8% for hyperactivity / inattention. Within each 'deteriorating' group, an increasing proportion of children were at risk of child psychopathology symptoms from age 3 to age 11, which means members of these groups

showed an increased risk of presenting with problem behaviours. However, it is important to note that the average proportion of children at-risk of conduct problems and hyperactivity / inattention within the 'deteriorating' groups appeared lower than that of the 'improving' groups. In other words, children in the 'improving' groups exhibit a higher level of conduct problems or hyperactivity / inattention between age 3 and age 11 compared to those in the 'deteriorating' groups on average, although children in the 'deteriorating' groups seem to show a concerning trend of deteriorating.

Across three child psychopathology symptom domains, there was always a 'high-risk' group where the majority of children within the group, ranging from 60% to 100%, exhibited a high risk of problem behaviours from age 3 to age 11. In other words, if a child is from the 'high risk' group, he/she is likely to show chronic problem behaviours. The 'high risk' group occupied 18%, 11.8%, and 6% of the studied child population in terms of internalising behaviours, conduct problems, and hyperactivity / inattention respectively. The 'high risk' groups identified by the present study suggested a group of children at high risk of developing chronic mental health condition(s). A much larger body of research investigates childhood chronic physical conditions compared to the research on childhood chronic mental health issues. Nevertheless, an increasingly growing awareness has been raised around the prevalence of childhood chronic mental health issues over the last decades. Slomski (2012) indicated that statistics showed mental health conditions, instead of physical health ones, ranked the top 5 disabilities affecting children in the US. Garg and his colleagues (2017) suggested that at least 20% of the child and adolescent population have a psychological or psychiatric disorder(s), some of which are chronic in nature. They further clarified that the most common mental health problems include anxiety disorders,

mood disorders, and disruptive behavioural disorders (e.g., ADHD). Chronic mental health issues are associated with chronic illnesses or other long-term physical health conditions (Care Quality Commission, 2019; Naylor et al., 2012). Risk factors are associated with childhood mental illness, which in turn increase the risk for children developing chronic mental health issues. Examples of such risk factors include maternal mental illnesses (Abel et al., 2019), poorer average cognitive ability, special educational needs, communication difficulties, single-parent household, lower household income, having siblings, being bullied by siblings, peer problems, not feeling safe in the local neighbourhood, etc. (Patalay & Fitzsimons, 2016). Some of these factors, e.g., poverty and children's verbal reasoning ability, were also risk factors for poorer SWM, as revealed in the present study.

7.2 Child Psychopathology Trajectory Group Membership and Spatial Working Memory

The present study found a link between children's SWM performance in early adolescence and the development of their childhood psychopathology symptoms. Children's SWM skills tended to differ by the child psychopathology trajectory group.

7.2.1 Child Psychopathology Impact on SWM by Trajectory Group

In general, atypical trajectory groups showed poorer SWM than the reference group [10] within a general child population, and the 'high risk' group [11] performed particularly poorly. This finding is consistent with some previous research with more selective and smaller samples (e.g., Ferrin & Vance, 2012; Saarinen et al., 2015; Shackman et al., 2006). As explained earlier in Chapter 1, the impact of children's psychopathology

[10] The reference group showed the lowest level of risk of child psychopathology symptoms.
[11] The 'high risk' group is the group with a high risk of chronic mental health conditions.

symptoms on their later SWM could be explained by some neuroscience and cognitive psychology theories (e.g., (Capaldi et al., 2012; Ruttle et al., 2011; Zahn–Waxler et al., 2000). For example, children with atypical internalising and / or externalising symptoms may show poor SWM because prefrontal cortical dopaminergic dysfunction or cortisol related HPA axis dysregulation causes 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. In addition, children from the 'high risk' group, i.e., children with a chronic mental health condition(s), are particularly vulnerable to ineffective use of the limited cognitive capacity, leading to failures in accomplishing cognitive tasks.

Children from the 'high risk' group exhibited high risks of problem behaviours at all the age points assessed in the present study. They are likely victims of developmental trauma. Van der Kolk (2015) described how children who repeatedly or continually experienced traumatic events from an early age could present with problem behaviours including ADHD, ODD, self-harming, anxiety, and substance use disorder; he explained that these children might experience the surrounding world in a fundamentally different way from their typically developing peers as the focus of their energy becomes suppressing the inner chaos caused by the dysregulation of the nervous system. Van der Kolk (2015) emphasized the importance of understanding these children's traumatic experiences as the first step of providing meaningful support.

7.2.2 Child Psychopathology Impact on SWM by Domain of Child Psychopathology

The link between child psychopathology and SWM tends to present more consistently with externalising behaviours, especially hyperactivity / inattention, than with internalising behaviours. The significant group differences between the 'typically developing' group of hyperactivity / inattention and the other three atypical trajectory groups remained significant even after controlling for all covariates of individual and family characteristics, regardless of which SWM measure was used. The same for the group differences between the 'early childhood limited' group of conduct problems and two of the three atypical trajectory groups i.e., the 'high risk' group and the 'improving' group. Similarly, the group differences between the 'high risk' groups and the other two atypical trajectory groups remained significant after taking into consideration all covariates for hyperactivity / inattention and conduct problems (but not when SWM was measured by SWM strategy, which will be discussed in the following paragraph). However, for internalising problems, the group differences between the 'no risk' group and the other three groups all disappeared in terms of SWM strategy after all covariates were controlled for. Furthermore, the 'high risk' group of internalising problems was not significantly different from the 'deteriorating' group in SWM regardless of which SWM measure was used. These findings contributed to the currently limited research around the link between internalising problems and SWM in a child population, as mentioned previously in the literature review; the findings were also consistent with the previous literature that externalising behaviours seem to be more strongly linked to deficits in SWM, but there is significant specificity by type, with ADHD being more consistent and more strongly

associated with impaired working memory in general (Martinussen et al., 2005; Schoemaker et al., 2013; Willcutt et al., 2005).

One possible explanation might be found in the study of Blanken and her colleagues (2017), which explored cognitive profiles of children with predominantly internalising symptoms, children with externalising symptoms, children with co-occurring internalising and externalising symptoms, and children with no problem in areas of attention / executive functioning, language, memory / learning, sensorimotor functioning, and visuospatial processing. Blanken et al. (2017), based on the data from 1177 school-aged children, suggested children with predominantly internalising symptoms and those with predominantly externalising symptoms showed distinctive cognitive profiles, where internalising symptoms linked to poor performance on verbal fluency and memory and externalising symptoms were associated with impairment of attention / executive functioning. Given that SWM is a domain of working memory, which is closely monitored by executive functioning, it is plausible to suggest that children with externalising behaviours rather than those with internalising problems are more likely to show poor performance on SWM tasks.

7.2.3 Child Psychopathology Impact on SWM by Measure of SWM

The link between child psychopathology and SWM tends to present more consistently when SWM was measured by SWM total errors than when it was measured by SWM strategy. When SWM was measured by SWM total errors (children with poorer SWM make more errors by selecting the wrong boxes on-screen), atypical trajectory groups showed significantly poorer SWM compared to the reference group, which presents with the lowest average risk of child psychopathology symptoms, after controlling for all

the covariates. It was consistently found across the three child psychopathology domains with only one exception[12]. The 'high risk' group also showed, in general, significantly poorer SWM in terms of SWM total errors compared to other atypical trajectory groups for each child psychopathology domain. However, when SWM was measured by SWM strategy (children with poorer SWM tend to search the right boxes randomly or using inconsistent strategies), there were mixed results across three child psychopathology domains regarding the group differences between atypical trajectory groups and the reference group. Firstly, all three atypical trajectory groups of hyperactivity / inattention showed significantly poorer SWM in terms of more frequently using inefficient strategies than the 'typically developing' group even after all the covariates were adjusted for. Secondly, the 'improving' and the 'high risk' group of conduct problems presented with significantly poorer SWM measured by SWM strategy compared to the 'early childhood limited' group, even after controlling for all covariates; however, there was no significant group difference between the 'deteriorating' group and the 'early childhood limited' group in the final model. Thirdly, for internalising problems, the trajectory group membership seemed to have little impact on SWM strategy: there was no significant difference in children's SWM strategy performance between the 'no risk' group and any of the atypical trajectory groups. Furthermore, for all three child psychopathology domains, the 'high risk' group performed as well as the other two atypical trajectory groups on SWM strategy. These results tended to suggest that child psychopathology symptoms could be more

[12] the 'deteriorating' group of conduct problems showed no significant group difference to the 'early childhood limited' group on SWM total errors even in the baseline model where none of the covariates was included as predictors. And their group difference in SWM strategy, although continued to be significant after controlling for most of the covariates, was no longer significant after controlling for children's verbal reasoning skills.

closely associated with impairments in children's SWM ability to hold and recall various pieces of information regarding the locations of visual-spatial stimuli on screen, as measured by SWM total errors, than with impairments in their ability to not only remember the locations of stimuli but also consistently follow a predetermined spatial sequence, as measured by SWM strategy. More specifically, these results implied high risks of child psychopathology symptoms might have a domain-specific impact on SWM: Children with a high risk of internalising problems and / or externalising symptoms are more likely to show impairments in their memory of random visual-spatial information than their peers, while their ability to make and follow plans using visual-spatial information could remain relatively unaffected.

The suggested domain-specific impact of chronic child psychopathology symptoms on SWM was premised on the understanding that the SWM includes at least two to-some-extent independent constructs as measured by SWM total errors and SWM strategy, respectively; one SWM construct is related to the ability to memorize randomly presented visual-spatial stimuli while another is associated with skills to organise the presented visual-spatial stimuli in order and subsequently follow the order; therefore, the latter SWM construct seems to not only a measure for SWM but also reflect the process of the central executive functioning monitoring SWM as described in the model of working memory (Baddeley, 2017). Thus, SWM strategy, as a measure of SWM in the present study, might also be a measure for some aspect of the central executive functioning (Voyer et al., 2017), which is in line with what Alloway et al. (2006, p. 1713) explained: "dynamic formats of visuospatial tasks involve executive functions". Therefore, the results of the present study could indicate the absence of effect of internalising symptoms or the weakened effect of

externalising symptoms on children's executive functioning skills in processing visual-spatial information (i.e., organising and recalling relevant information in order), in comparison to their effects on temporary memory of randomly presented visual-spatial stimuli (i.e., the locations). However, it is still unclear why this is the case. Further research is needed on the structure of SWM and the interactive relationship among different components of SWM and executive functioning to help explain such phenomenon. Nevertheless, the cognitive load theory (Sweller et al., 2011) might provide a possible explanation from another perspective.

The cognitive load theory postulates that "there is no conceivable central executive, apart from long-term memory" and it suggests individuals' knowledge stored in long-term memory is what people utilise during problem-solving, i.e., knowledge acts like a central executive (Sweller et al., 2011, p. 35). Given the relative stability of knowledge at a certain age, it seems reasonable to discover that children's internalising or externalising behaviours showed a reduced impact on their organizing of visual-spatial information and subsequent planning at age 11 if such activities mostly relied on their knowledge.

7.2.4 The Role of Children's Verbal Ability

Children's verbal ability appeared to play a role in explaining the association between some of the child psychopathology symptoms and SWM. For example, the significant group differences between the 'low risk' group or the 'high risk' group of internalising problems and the 'no risk' group disappeared after children's verbal ability i.e., ability to recognise and name the similarity among words was controlled for in the final model which already considered the effects from other individual-level or family-level covariates, e.g., age, gender, ethnicity, and SES. It may suggest that children with

similar individual characteristics and family background could adopt effective strategies to organize visual-spatial information if they have stronger verbal ability despite being at risk of internalising problems, possibly because stronger verbal ability could predict executive functioning skills (Botting et al., 2017). However, children with symptoms of internalising problems are more likely to show impairments with verbal ability, including reading, than their peers (Blanken et al., 2017; Francis et al., 2019). Thus, interventions that target improving children's verbal ability could be crucial for alleviating internalising problems and supporting the development of non-verbal executive functioning skills.

The present study also detected the moderating effect of children's verbal ability between externalising behaviours and SWM strategy; however, such effect appeared less salient compared to that between internalising behaviours and SWM strategy. The group difference in SWM strategy between the 'deteriorating' group of conduct problem and the 'early childhood limited' group became insignificant after taking into account children's verbal ability. However, the significant group differences between the reference group and two other atypical trajectory groups of conduct problems remained significant after controlling for children's verbal ability; so were the group differences between the reference group and all three atypical trajectory groups of hyperactivity / inattention. In summary, the moderating effect of child verbal ability observed between internalising problems and SWM strategy was almost unobservable for both domains of externalising problems. This finding is consistent with some studies (e.g., Blanken et al., 2017; Bornstein et al., 2013), which suggested children's verbal ability was associated with internalising behaviours but not externalising behaviours. Blanken et al. (2017) reported poor verbal fluency and memory associated with internalising problems but not externalising problems.

Bornstein et al. (2013) explored the relationship among children's language skills, internalising behaviour problems and externalising behaviour problems using two independent longitudinal studies: the first study assessed 85 children when they were at average ages of 4.5 years and 7 years; the second study obtained data from 139 children when they were at average ages of 4 years, 10 years, and 14 years. Bornstein et al. (2013) reported, in both studies, children's language deficiency in early childhood predicted their internalising problems at later times; however, it was not true for externalising problems.

Nevertheless, some other studies (e.g., Levickis et al., 2018; Menting et al., 2011) suggested children's language skills could predict subsequent externalising behaviours. Levickis et al. (2018) assessed 771 children's language by Clinical Evaluation of Language Fundamentals (CELF) and social, emotional and behavioural difficulties by SDQ at ages of 4, 5, and 7 years; their results indicated children with language difficulties showed significantly more externalising problems at all three age points, but the same was not true for internalising problems. Menting et al. (2011) followed 615 children from the age of 4 years to 9 or 10 years. They reported that children's receptive language skills measured at ages 7 or 8 predicted the growth of their externalising behaviours. Children with stronger language skills and these with poorer language skilled showed, respectively, decreased and increased teacher-reported externalising behaviours. Therefore, because there were mixed results regarding the relationship between language ability and internalising problems or externalising problems, it remains unclear why children's verbal ability only explained the association between children's internalising problems and SWM strategy, but not between externalising problems and SWM strategy.

7.2.5 The ‘Deteriorating’ Group of Conduct Problems: An Exception

As described previously, when SWM was measured by SWM total errors, atypical trajectory groups performed significantly worse than the reference group on SWM tasks across the three child psychopathology domains with only one exception. The ‘deteriorating’ group of conduct problems showed no significant group difference compared to the ‘early childhood limited’ group, even in the baseline model where none of the covariates was included as predictors. When SWM was measured by SWM strategy, no significant group difference was found between the ‘deteriorating’ group of conduct problems and any of the other three trajectory groups. These results are to some extent in line with the findings of some previous studies (e.g., Oosterlaan et al., 2005; Thorell & Wåhlstedt, 2006) that suggested no association between working memory and ODD / CD. On the contrary, some other studies (e.g., Griffith et al., 2019; Saarinen et al., 2015) reported ODD and / or CD was related to working memory. To clarify, the present study found that trajectory group membership of conduct problems impacted on children’s SWM: for example, children from the ‘early childhood limited’ group significantly outperformed the ‘improving’ and the ‘high risk’ groups no matter which measure of SWM was adopted; when SWM was measured by SWM total errors, the ‘high risk’ group showed significantly poorer SWM than the ‘deteriorating’ and the ‘improving’ groups. There might be, therefore, some alternative explanation for the absence of negative impact of the ‘deteriorating’ group membership on children’s SWM skills in the present study, given that the results indicated children from the ‘deteriorating’ group performed, on average, as well as their typically developing peers. One possible explanation could be that the present study explored children’s problem behaviours from the age of 3 years to 11 years, where the

dramatic increase of the prevalence of conduct problems may not yet be fully captured for children in the 'deteriorating' group. Gutman et al. (2019) investigated the trajectory groups of conduct problems following 17,206 children from ages 3 to 14 years using data from the UK Millennium Cohort Study (MCS). They reported an adolescent-onset group as one of the four identified trajectory groups, which showed a similar behaviour trajectory to the 'deteriorating' group identified by the present study. Gutman et al. (2019) described the adolescent-onset group presented with a substantial increase in the prevalence of conduct problems from around 30% at age 7 years to around 50% at age 14 years, and the prevalence will likely continue to rise after age 14 to adulthood (Odgers et al., 2007). Hence, the negative impact of the 'deteriorating' group membership on SWM may start appearing at a statistical level after age 11. It is, therefore, important to provide early SWM intervention before the age of 11 years for children who exhibited a history of conduct behaviours at deteriorating rates.

7.2.6 Protective and Risk Factors for SWM

A list of protective / risk factors was consistently identified, across the three domains of child psychopathology, for children's SWM at age 11. Higher levels of children's verbal ability and having a mother with a university degree, as protective factors, were significantly correlated with better SWM performance. Risk factors included poverty and being Black or Black British, which were always related to poorer SWM performance. These findings were consistent with previous research (e.g., (Blasiman & Was, 2018; Flouri et al., 2018; Leve et al., 2005; Mesman et al., 2001). The results also showed that girls tended to make fewer search errors in the SWM task. However, no gender difference was found regarding their use of SWM strategies. In other words, being female was a

protective factor for children's SWM skills in storing and recalling visual-spatial information. Similarly, Duff and Hampson (2001) also reported, based on assessments of 90 participants (44 females) aged from 18 to 34 years, females outperformed males on an SWM task in terms of making fewer errors and using less time to recall the location of stimuli. On the contrary, Voyer et al. (2017) suggested that males showed an advantage in completing SWM tasks in their meta-analysis with 98 samples with mean ages from 3 to 86 years. The conflicting results may suggest gender difference on SWM may alter in the direction depending on the nature of SWM tasks as explained by Voyer et al., (2017): females tended to show better performance on SWM tasks involving remembering locations [like the SWM task used by Duff and Hampson (2001), and the measure of total errors in this study]; males seemed to show an advantage in SWM tasks where sequencing also matters. In the present study, results indicated female advantage when dealing only with locations of stimuli, but no gender difference was found when SWM was measured by SWM strategy, which tested participants' ability to remember both the locations and the sequence of visual-spatial stimuli.

7.3 Does Child Psychopathology Affect Child Academic Outcomes through Spatial Working Memory?

Children's SWM skills, measured by both total errors and strategy, were tested as a mediator between children's psychopathology and teacher-reported academic performance.

7.3.1 Mediating Effects of SWM Total Errors and SWM Strategy

As indicated by the regression modelling results, children from atypical trajectory groups across three child psychopathology domains showed significantly poorer SWM skills measured by SWM total errors in general, but children from the 'deteriorating' group of conduct problems performed as well as their typically developing peers. Results of the mediation analysis showed the same pattern: SWM total errors was a significant mediator; it explained some of the group differences in teachers' ratings on English, maths, and science between the references groups and all atypical trajectory groups but the 'deteriorating' group of conduct problems. It could be, as explained previously, the impact of the 'deteriorating' group of conduct problems on children's SWM skills and academic performance might be identified at a later age rather than age 11 years. Further studies following participants to a later age will be needed to examine such hypothesis.

The regression modelling results showed children from atypical trajectory groups of externalising problems displayed significantly poorer SWM skills measured by SWM strategy compared to their typically developing peers, although the same did not apply to children from the 'deteriorating' group of conduct problem, while children from any of the atypical trajectory groups of internalising problems performed equally well as their typically developing peers in terms of SWM strategy. In the same vein, results of the mediation analysis suggested SWM strategy explained some of the group differences between reference groups and some of the atypical trajectory groups of externalising problems, i.e., the 'high risk' group of conduct problems, the 'improving' and the 'high risk' groups of hyperactivity / inattention. However, SWM strategy was not a mediator for the impact of internalising problem trajectory group membership on academic

performance. Such findings are consistent with previous research that suggested children's academic performance seemed to be more consistent or more strongly related with externalising behaviours primarily the domain of hyperactivity / inattention than with internalising problems (e.g., Arnold et al., 2020; Ende et al., 2016; Patalay & Fitzsimons, 2016).

In summary, SWM skills appeared to be a stronger mediator when it was measured by SWM total errors than when it was measured by SWM strategy. As mentioned previously, SWM total errors were the measure of children's ability to hold and recall multiple pieces of information regarding the locations of visual-spatial stimuli on-screen; SWM strategy measured their ability to not only remember the locations of stimuli but also consistently follow a predetermined spatial sequence. Therefore, the present study tended to suggest, even after taking into account differences in children's age, gender, verbal ability, family SES, maternal education and maternal depression, high risks of child psychopathology symptoms could associate with SWM impairment in terms of temporarily storing and recalling locations of visual stimuli which could, in turn, predict lower teacher ratings on English, maths and science.

7.3.2 The Vulnerable Group

For children with externalising behaviours, and these in the 'high risk' groups of all three child psychopathology domains, poorer academic performance across three subjects was predicted by SWM deficit regardless of the measure. It suggested these children are more likely to show less satisfactory SWM skills, leading to poorer academic performance.

7.3.3 Implications

Indeed, some previous studies (Carroll et al., 2005; Clark et al., 2002; Pedersen et al., 2019; Taanila et al., 2011) reported negative associations, either concurrently or longitudinally, between children's academic performance and their internalising or externalising behaviours. The present study, after finding the link between child psychopathology symptoms and SWM, further indicated that SWM could explain the impact of child psychopathology symptoms on academic performance. This finding has important implications for professionals working to support school-aged children whose academic performance appears below the expected range; that is, SWM could be an area to explore for prevention, assessment, and intervention work.

Some researchers (Fanari et al., 2019; Soltanlou et al., 2019) suggested that SWM is one of the best predictors (another example is central executive functioning) for children's mathematic skills, while relatively limited research investigates the relationship between SWM and literacy skills, or between SWM and science skills. The present study indeed found that children's maths results, compared to English and science, were more strongly correlated with SWM skills at age 11. However, it was beyond the scope of the present study to examine whether the mediating effect of SWM appears the strongest for maths than English and science.

7.4 Implications for Educational Psychology Practice

The present study surveyed professionals working in the field of educational psychology to obtain their views about the credibility of the child psychopathology – SWM link and its implications on their practice. Survey results showed that more than half of the participants (65.9%) described such a link as somewhat or highly believable. The present

study also collected information around participants' professional experiences, i.e., years of practice; frequency working with children of internalising behaviours / externalising behaviours / poor SWM and their self-perception of competence, to examine whether professionals' work experiences or self-perception of competence could have an impact on their views about the credibility of the child psychopathology – SWM link. Survey results showed no link between years of practice / self-perception of competence and participants' view about the credibility of the link. Participants' frequency of working with children with internalising problems or poor SWM did not affect the outcome either. However, participants' frequency of working with children with externalising problems was positively associated with the extent to which they believed in the link, which could be explained by one of the main findings in the present study; that is, the link between child psychopathology and SWM tends to present more consistently with externalising behaviours especially hyperactivity / inattention than with internalising behaviours.

The child psychopathology – SWM link, according to survey participants, has implications for several areas of professionals' work in the field of educational psychology, including interventions / provisions, hypothesis formulation, assessment, consultation, and systemic work, which are discussed in detail below.

7.4.1 Interventions / Provisions

The link highlighted the importance of interventions / provisions that could support the development of children's SWM skills and meet their social emotional and mental health (SEMH) needs. On the one hand, the effectiveness of SWM interventions remains unclear but research seemed to suggest that improving executive control / attention skills

is the key for intervention effectiveness (see Rowe et al., 2019 for a systematic review). Some researchers (e.g., Abou Sleiman & Kechichian Khanji, 2021; Rudebeck et al., 2012) reported their interventions showed some positive effect in improving participants' SWM. For example, Abou Sleiman and Kechichian Khanji (2021) reported that 9 Lebanese children with ADHD showed significant gains in sequential and static SWM skills after six 30-minute sessions of different activities. The activities were memory tasks of two types i.e., focusing on static process and dynamic process respectively and were increasing in level of difficulty. However, this study lacks generalisability due to the small sample size, no control group, or adjustment of covariates in quantitative analysis. Rudebeck et al. (2012) divided 56 neurologically healthy young people aged around 25 years into training group and control group, and the training group received 20 computerised SWM training sessions with each lasted for 20 minutes; it was reported that the training group made significantly more significant progress on a non-verbal intelligence test where participants needed to choose one out of six patterns to complete 5 × 3 matrices for 29 trials. However, the study participants were young adults rather than children, and it did not assess whether the training effect remained long-term. On the contrary, Sjöwall et al. (2017) examined the long-term effect of increased physical activities including aerobics, boxing, skipping rope, running, and play on working memory including SWM. They indicated no significant difference in performance on working memory tasks was found between children aged 6 to 13 years who had daily physical activities at a school for two years and their peers from another school who only engaged in physical activities for two days a week. Rowe et al. (2019) stressed the importance of applying working memory interventions including SWM interventions in everyday contexts and reviewed 18 studies which examined the

effectiveness of non-computerised working memory interventions for children aged from 4 to 11 years; the review summarised that working memory interventions that showed a positive effect were these require attention / executive control skills for both storing and processing information, including explicitly teaching cognitive strategies, physical activities such as martial arts and yoga, phoneme awareness training, and imaginary play. On the other hand, successful universal or specific interventions for children with SEMH needs tended to adopt a positive approach, which avoids a child deficit model and focuses on developing positive relationships and promoting feelings of security (see Carroll & Hurry, 2018 for a review).

7.4.2 Hypothesis Formulation and Assessment

The link could support educational psychology professionals' hypothesis formulation and assessment work when working with children showing SEMH needs and / or poor SWM. Given that the development of childhood psychopathology symptoms correlates with early adolescent SWM skills, educational psychology professionals could hypothesize that children who present with SEMH needs, especially those with a history of SEMH needs, may also experience difficulties in SWM tasks and vice versa. The hypotheses, in turn, could guide subsequent assessment. For example, the subscales of Recall of Designs and Pattern Construction in the British Ability Scales, and Complex Figure Drawing for assessing SWM skills; Strengths and Difficulties Questionnaire (Goodman, 1997) for children's internalising or externalising behaviours. It was also mentioned that, via consultations or systemic work, the child psychopathology – SWM link could support children's important others, for example, parents, teachers and school, in understanding children's problem behaviours, acting as advocates, and being motivated to

adopt a positive approach in interacting with these children, all of which contribute to positive outcomes for children's development (Carroll & Hurry, 2018).

7.4.3 A Summary of Implications of the Child Psychopathology-SWM Link for Educational Psychology Practice

According to the bioecological theory of human development (Bronfenbrenner, 2005), individuals' development involves interaction between individual characteristics and his environments; the environment includes four interrelated systems – the microsystem i.e., the immediate environments such as home, school and peer group; the mesosystem i.e., interactions between different microsystems; the exosystem i.e., contexts that indirectly affect one's development such as parents' workplace, and the macrosystem e.g., culture, social values. The bioecological theory of human development provides a framework which could summarise the impact of the psychopathology – SWM link for the practice of educational psychology professionals: Educational psychology professionals, when working with a child who presents with internalising / externalising problems and / or poor SWM, could consider gathering information about the trajectory of his internalising / externalising behaviours and assessing his SWM skills (individual characteristics), raising awareness about this link in his supporting network (the microsystem and mesosystem), and considering the impact of any relevant cultural background (the macrosystem). Nevertheless, as emphasized by some survey participants, more research is required to understand the direction of the link and its underlying mechanisms, without which it will be difficult to plan any prevention work or establish the focus of assessment or intervention work.

Chapter 8

Conclusion, Study Strengths and Limitations

There were several main findings regarding a general child population in the present study. Firstly, across three domains of child psychopathology, i.e., internalising problems, conduct problems, hyperactivity / inattention, a group of children exhibited high risks of problem behaviours at age 3, 5, 7, and 11 years. Secondly, children showing a higher risk of hyperactivity / inattention from ages 3 to 11 years were more likely to show, at age 11, poorer SWM skills in terms of temporarily storing multiple pieces of visual-spatial information as well as manipulating the information in sequence, so were children with a higher risk of conduct problems except for a group who exhibited a deteriorating trend of conduct problems (more research is required to examine the SWM in this group at later ages). Children with a higher risk of internalising problems tended to show poorer SWM skills in temporarily holding and recalling visual-spatial information. Thirdly, SWM skills could explain some of the impacts of child psychopathology symptoms, especially the domain of hyperactivity / inattention, on teacher ratings of children's academic performance in English, maths, and science. Fourthly, educational psychology professionals tended to report the link between child psychopathology symptoms and SWM as more believable when they had more experiences with externalising behaviours; they also explained that such link could affect their practice in different areas, including intervention, hypothesis formulation, assessment, consultation, and systemic work.

The present 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, a robust adjustment for confounders and covariates in the analysis, and a step further to investigate the impacts of children's emotional and behavioural symptoms on their academic performance via SWM. The present study also explored the implications of the main findings for real-life practice from educational psychology professionals' perspectives. 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 the present study could not do as it 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). The present study 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, the present study conducted GBTM for all three domains without controlling for comorbidity. Thirdly, as already discussed, the present study cannot determine, given the study design and the data available, if the associations the present study 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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Appendix 1

Spatial Working Memory and Child Psychopathology - The implication of their association for EP work

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Start of Block: Information Sheet

Information Sheet for Online Survey Participants

1. Title of the research: Spatial Working Memory in Young Adolescents with Different Childhood Trajectories of Internalising, Conduct and Hyperactivity/inattention Problems

2. Researcher: Ye Kuang, Year three trainee educational psychologist, UCL Institute of Education

3.1 Purpose of the research: Children's internalising behaviours and externalising behaviours impact on learning. However, there is limited research on the specific impact of such behaviours on spatial working memory (SWM), which is strongly related to cognitive ability and children's learning. This thesis project explored distinct trajectories of internalising behaviours and externalising behaviours (conduct problems and hyperactivity/inattention) in a large general-population sample of children followed from age 3 to age 11 years. The project then assessed the role of these trajectories in SWM performance at age 11 years. **3.2 Main results of the quantitative data analysis**: Poor spatial working memory measured at age 11 was most consistently found in children with chronically high levels of internalising behaviours (i.e., emotional symptoms; peer problems) or externalising behaviours (i.e., conduct problems; hyperactivity/inattention). **3.3 Purpose of the online survey:** The researcher is interested in the implications of the data analysis results for professionals' practice in the field of educational psychology. Therefore, the researcher plans to gather these professionals' views via anonymous online survey about how the results (**3.2**) could affect their practice.

4. Who can participate in the online survey? Anyone who considers themselves to be professionals working in the field of educational psychology.

5. What will happen to participants in the online survey? Consent is assumed when you choose to proceed with the study at the end of this information sheet. Duration The survey can be completed in 5 - 10 minutes or so. What will be involved? You will be asked a series of questions. All the questions are related to your experiences and views about children's spatial working memory and internalising / externalising behaviours.

6. How will the information be stored? The researcher will be the only person having access to the data. All the collected information will be kept strictly confidential. The data will be collected and stored in accordance with data protection legislation (GDPR and DPA 2018), secured against unauthorised access.

7. Anonymity The findings from the survey may be shared with my colleagues from the UCL Institute of Education, or other form of publication or presentation. However, all information provided will remain anonymous.

8. Benefits Your participation in this research is likely to contribute to the understanding of the relationship between children's internalising / externalising behaviours and their spatial working memory, and how such relationship may impact on your professional practice. This research project is planned to be completed in Jun, 2021. A summary of the findings of this research will be offered to participants on request.

9. Data Protection Privacy Notice The controller for this project will be University College London (UCL). The UCL Data Protection Officer provides oversight of UCL activities involving the processing of personal data and can be contacted at data-protection@ucl.ac.uk This 'local' privacy notice sets out the information that applies to this study. Further information on how UCL uses participant information from research studies can be found in our 'general' privacy notice for participants in research studies following this link: https://www.ucl.ac.uk/legal-services/privacy/ucl-general-research-participant-privacy-notice The information that is required to be provided to participants under data protection legislation (GDPR and DPA 2018) is provided across both the 'local' and 'general' privacy notices. The lawful basis that will be used to process any personal data is: 'Public task' for personal data and 'Research purposes' for special category data. The only type of personal data will be collected by this study is *occupation* such as: *please tell us the title of your current role and previous roles*. If you are concerned about how your personal data is being processed, or if you would like to contact us about your rights, please contact UCL in the first instance at dataprotection@ucl.ac.uk

10. Contact details If you have any questions about the research, please do not hesitate to contact the researcher via email at ye.kuang.17@ucl.ac.uk or the researcher's Professional EP Research Supervisor Dr Tom Connor at t.connor.14@ucl.ac.uk.

Please select one of the following:

- ○ I wish to proceed with the study.
- ○ I do not wish to proceed with the study.

Skip To: End of Survey If Please select one of the following: = I do not wish to proceed with the study.

End of Block: Information Sheet

Start of Block: Background information

Please select from below the best description for your role.

- ○ Trainee Educational Psychologist
- ○ Main Grade Educational Psychologist
- ○ Senior Educational Psychologist
- ○ Principal Educational Psychologist
- ○ Assistant Educational Psychologist
- ○ Other _____

How many years have you been practising within the field of educational psychology?

- ○ Less than 3 years
- ○ 3 - 5 years
- ○ 5 - 10 years
- ○ More than 10 years

Please select from below description(s) that apply to your previous role(s) (please select as many as apply).

- ☐ Teacher
- ☐ Teaching assistant / Learning support assistant
- ☐ SENCo
- ☐ Assistant Educational Psychologist
- ☐ Early Years practitioner
- ☐ Senior leadership team member
- ☐ Other _____

End of Block: Background information

Start of Block: Experience

How often do you work with children and young people (CYP) with internalising behaviours*?
**internalising behaviours - depressive or anxiety symptoms and peer problems*

- ○ Rarely
- ○ Sometimes
- ○ Quite often

How often do you work with CYP with externalising behaviours*?
**externalising behaviours - hyperactivity and antisocial or 'acting-out' behaviours*

- ○ Rarely
- ○ Sometimes
- ○ Quite often

How often do you work with CYP with poor spatial working memory*?
**spatial working memory - the cognitive ability to manipulate visual-spatial information; examples of measures include the CANTAB Spatial Working Memory test*, *British Ability Scales - the subscales of Recall of Designs and Pattern Construction, Wechsler*

Intelligence Scale for Children - the subscales of Block Design and Visual Puzzles, and Complex Figure Drawing.

- ○ Rarely
- ○ Sometimes
- ○ Quite often

The four stages of competence (Noel Burch, 1969) suggest that people go through four stages when learning something new:
1. Unconscious incompetence - I am not aware of what I don't know
2. Conscious incompetence - I am aware of what I don't know
3. Conscious competence - I am aware of what I know
4. Unconscious competence - I don't need to be aware of what I know as it becomes an instinct

Which stage do you think you are in regarding your knowledge around internalising behaviours, externalising behaviours and spatial working memory?

	Unconscious incompetence	Conscious incompetence	Conscious competence	Unconscious competence
Internalising behaviours	○	○	○	○
Externalising behaviours	○	○	○	○
Spatial working memory	○	○	○	○

Based on your experience, to what extent do you believe the following statement?'*There is a link between spatial working memory and internalising behaviours / externalising behaviours.*'

- ○ Extremely believable
- ○ Somewhat believable
- ○ Neither believable nor unbelievable
- ○ Somewhat unbelievable
- ○ Extremely unbelievable
- ○ I am not sure

End of Block: Experience

Start of Block: Implication for EP work

My thesis project used data from the UK's Millennium Cohort Study. It followed 12,589 children from age 3 to age 11 years. It found that poor spatial working memory measured at age 11 was most consistently found in children with chronically high levels of internalising behaviours (i.e., emotional symptoms; peer problems) or externalising behaviours (i.e., conduct problems; hyperactivity/inattention).

What is the first word(s) / phrase(s) / sentence(s) that appears in your mind after reading the statement as above?

_____

Which one or more areas of educational psychology work could be affected if the above statement is true (please select as many as apply)?

- [ ] Assessment
- [ ] Consultation
- [ ] Intervention
- [ ] Systemic work
- [ ] None of the above
- [ ] Other _____

Please describe, with examples from your work and personal experience, how could the selected areas of your work be affected?

_____

Any other comments?

_____

End of Block: Implication for EP work

Appendix 2

Supplementary Table 1

Survey Participants' Response Rates for Each Multiple-Choice Question

Question	No. of Responses	Response Rate
Please select from below the best description for your role.	48	98%
How many years have you been practising within the field of educational psychology?	48	98%
Please select from below description(s) that apply to your previous role(s) (please select as many as apply).	48	98%
How often do you work with children and young people (CYP) with internalising behaviours?	41	84%
How often do you work with CYP with externalising behaviours?	41	84%
How often do you work with CYP with poor spatial working memory?	41	84%
Which stage do you think you are in regarding your knowledge around internalising behaviours, externalising behaviours and spatial working memory?	41	84%
Based on your experience, to what extent do you believe the link?	41	84%
Which one or more areas of educational psychology work could be affected if the above statement is true (please select as many as apply)?	41	84%

Note: Total number of responses is 49.

Appendix 3

Supplementary Table 2

Participants Answers to Open Questions

Participant ID	What is the first word(s) / phrase(s) / sentence(s) that appears in your mind	Please describe, with examples from your work and personal experience, how could the selected areas of your work be affected?	Any other comments?
1			
2			
3			
4			
5			
6			
7			
8			
9	just spatial working memory?	Identifying more strategies on supporting the internal / external beahviours	
10	Interested to know the link with poor spatial wm.	It would help me to explore this area more as I think little is known in this area, so i would explore it more when information gathering.	Thank you for raising awareness.
11	what about other ages?		
12			
13	I wouldn't have linked the two		
14	chronically high levels of...	better advising/implementing targeted intervention for young people at the PRU and Youth Offending	
15	Link between emotional needs and cognition	Considering appropriate assessments, formulating hypotheses, planning interventions	

16	correlation does not mean causation	To more often assess spatial working memory, to look at ways children can be taught strategies to support their spatial skills, to share information with teachers and offer training at school	
17	Why?	Need more accurate measures of Spatial WM - the WMTB-C is quite out of date and hasn't been replaced with a similar test of WM functioning. There is relatively little literature specifically on interventions for spatial cognition difficulties, including Spatial WM difficulties.	
18	Interesting, wondering about directionality and causality.	engagement with literature	
19	it must be very frustrating for children who struggle with spatial working memory	It would be useful information to bring to consultation and discuss with parents and teachers; it would be a useful concept to assess with the child and then identify appropriate intervention that could help support spatial ability.	
20	makes sense	need to share understanding of the impact of these difficulties at teacher, family and child level. Adds to understanding CYP presentation and suggests these difficulties need to be identified through assessment with follow through of evidence based interventions	
21	Why? What's the mechanism? Is there a causal relationship?	A better understanding of this link might help us to generate hypotheses and offer possible new understandings of a child's presentation. This can help those involved view the child differently and may lead to a different action plan being generated.	A correlation alone isn't going to change EP practice - we'd need to know that this is more than a statistical artefact (common in large scale studies)
22	Chronically high levels	Teaching styles would need to be altered to cater for 'chronic' levels	

23	Surprising and interesting, I want to know more.	Suggestions for intervention would be altered potentially. It could be more of a focus in consultation and assessment.	
24	What do we do with this information now?	Exploration of spatial working memory skills with CYP with SEMH needs, including further thinking about the links between SWM and SEMH, what this might look like in the CYP's lived reality. May inform intervention/support/advice	Very interesting! Thanks!
25	Lack of understanding of behaviour	Focus assessment on spatial skills for children with internalising/externalising issues. Re-frame behaviour in consultations. Broaden intervention offer with int/ext behavioural difficulties	
26	very under researched area		
27	I have never considered this as a direct link, although I recognise more generally the connection between academic or cognitive difficulties and internalising and externalising behaviours.	If there was a reliable connection between spatial working memory and externalising/internalising behaviours, I might assess spatial working memory more often. I might also raise it in consultations and interventions could be recommended that target spatial working memory in some way, if this was the underlying cause of the behaviours.	It's an interesting link to think about, although without further explanation for why this would be I would currently be inclined to see this as correlation rather than causation
28	Very useful evidenced based research	Further exploration of how these elements are linked for individuals in consultation and making staff aware would be useful. Disseminating knowledge to schools and staff in training and systemic work would be helpful too. Making explicit the link following assessments but also bearing how difficult a child with internalizing and externalising behaviours might find these types of assessments and tailoring appropriate and adjusted style and task	This is very interesting research! Thankyou!

29	Interesting	I would use this as a hypothesis and it would help inform the assessment tools I use and questions at consultation	This is a very interesting and innovative piece of research
30	Trauma	Detailed early relational and experiential history needed from caregivers. Cognitive assessment as well as therapeutic assessment of SEMH... using play and art therapy techniques - not just verbal interaction. Multi-modal intervention focusing on emotional, behavioural needs plus elements from the neurosequential model to respond to early neurological disruption. For system around child and child herself - enhance understanding of the links between feelings, thoughts, behaviour, body and both current trigger/environment factors, and past influences in designing appropriate response, prevention and direct therapeutic work.	
31	Dry	Focus outcomes and recommendations	
32	That makes sense from a cognitive load perspective that these SEMH variables impact on that child's ability to take on additional information	Drawing on this relevant research to help teachers and parents understand the significant impact SEMH needs may have on learning	
33	That I should be more thorough in checking about working memory difficulties when I get referrals for children with internalising and/or externalising behaviours.	Children with externalising behaviours and memory difficulties "acting out" in a lesson whenever they don't know the answer to something. Children with internalising behaviours and memory difficulties associating school achievement with self-worth and having very low self-esteem.	Very interesting piece of research ☺
34	That's interesting	It can impact how we negotiate traded time	

35	Makes sense as their behaviour is a reflection of their feelings and frustration		
36	Executive dysfunction	By pre-empting spatial WM difficulties in CYP with ext/int problems and offering support alongside the usual interventions for emotional issues.	
37	cognitive load	We already consider that children with emotional or behavioural difficulties may not have the cognitive capacity left to focus on learning however we could look at specific interventions to support in this area.	
38	Interesting, I'd like to find out more about that.	Questioning CYP, school staff and families specifically about this aspect of ability and performance. Including spatial memory activities in assessments (I already frequently use CFD). Raising awareness in schools of this finding, and gelling them to be more alert to it, and intervene appropriately.	
39	Correlation specificity difficulties	Assessment-key indicators; consultation-interacting factors explaining behaviours; intervention: targeted approaches	
40	So what	Case work, consultation,	Need more information around group variance
41	Managing worksheets	I am assuming that visual spatial reasoning skills are relevant to many areas of learning that are not always recognised by teachers or in fact EPs. If these links were more prominent in our minds perhaps they would lead to a greater focus in assessment and subsequent recommendations for change. Language is often centred upon for assessment and intervention as the link between language and learning has become clearer over the years. Yet I imagine many youngsters are impacted by spatial difficulties affecting access to learning, maths, geography, science and subsequently affecting self-esteem , confidence and	I find this really interesting as I have worried about the lack of attention to visual spatial and spatial reasoning skills from psychologists.

		motivation. It would be great to see recognition in teachers of the importance of spatial reasoning for learning with a view to mediating its development, particularly in pupils who might face the most disadvantage. For older pupils still struggling, effective interventions could be focused upon to alleviate difficulties. Intervention	
42	Chronically	I really don't know	
43	This makes complete sense and I will place more emphasis on this link when I reflect on such cases	Including this finding throughout all my practice, as a part of my formulation i.e. in the reflections of a EHCNA, supporting colleagues in forming outcomes during a consultation.	This has been very empowering as I have just completed a Psych Advice for a YP with similar needs, just wish I had read your email earlier! Good Luck! just wish I had read your
44	not surprising	Sharing knowledge about emotions, thoughts and behaviour in many contexts, and what they might portray	It takes time to think about and unpick what and how CYP present
45	tell me more	it would be filed, cross referenced, tested against what i know and what i don't know. and we would come to a formulation where upon we might say something like: this might be why you and we could try this to	thanks
46	Curiosity	Assessment- include more spatial memory assessment when working with emotional and behavioural difficulties. Consultation- exploring this understanding with others. Systemic work-training for school staff. Intervention- perhaps working on	

		more physical, kinaesthetic tasks as well as interventions targeted at emotional literacy	
47	chronically high levels	systems / multi agency work	
48	Interesting		
49	Interesting		

Supplementary Table 3

Initial Codes and Themes of Thematic Analysis

Initial Codes	Themes	Final subthemes	Themes
Intervention	Intervention	**this link could support informing specific interventions / provisions.**	
Formulation	Formulation and Assessment info gathering can be two subthemes under a theme.	**This link could guide hypothesis formulation.** **This link could affect assessment work**	
Systemic work			
Empathy, raise awareness	raise awareness can be realized by consultation and Systemic work	**raising clients' awareness of the link via consultation and systemic work**	
Assessment info gathering	**New: linking the finding to existing knowledge**	**this link is in line with some of their existing knowledge**	**Reflections about the link**
Surprised / not surprised by the link			
More questions; be cautious	More questions and Surprised and raise awareness can be merged and then split to two: Resonate - raising awareness; Cautious – more research is needed	**More research is needed**	

Appendix 4 Supplementary Tables S13 to S18

Tables S13/S14/S15/S16/S17/S18 present regression modelling results with SWM as the dependent variable and child psychopathology trajectory membership as the independent variable. The regression analyses were conducted without the missingness analysis (i.e., multiple imputation) to obtain R2.

Table S13

Regression Estimates [coefficients (SE) & standardised coefficients] of Internalising Problem Group Membership on SWM Total Errors

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Internalising Behaviours (Ref: No risk)								
Deteriorating	5.13 (.86) ***	0.07***	4.59 (.85) ***	0.06***	3.65 (.87) ***	0.05***	3.15 (.89) ***	0.04***
Low risk	3.29 (.47) ***	0.08***	3.35 (.46) ***	0.08***	2.18 (.47) ***	0.05***	1.72 (.47) ***	0.04***
High risk	7.65 (.57) ***	0.16***	7.53 (.55) ***	0.15***	5.02 (.64) ***	0.10***	3.62 (.61) ***	0.07***
Age at Sweep 5			-.33 (.06) ***	-0.07***	-.36 (.06) ***	-0.08***	-0.39 (.05) ***	-0.08***
Gender (Ref: Male)								
Female			-1.11 (.40) **	-0.03**	-1.06 (.40) **	-0.03**	-1.31 (.39) **	-0.04**
Poverty					5.93 (.68) ***	0.12***	4.41 (.70) ***	0.09***
Ethnicity (Ref: White)								
Mixed					.87 (1.47)	0.01	1.38 (1.45)	0.01
Indian					-.84 (1.75)	-0.01	0.35 (1.71)	0.003
Pakistani and Bangladeshi					.28 (1.14)	0.003	0.07 (1.28)	0.001
Black or Black British					5.23 (1.72) **	0.05**	6.10 (1.63) ***	0.06***
Other (Inc Chinese)					-2.55 (2.35)	-0.01	-2.37 (2.31)	-0.01
Maternal Education								
Has 1st degree					-6.22 (.55) ***	-0.12***	-4.89 (.57) ***	-0.10***
Maternal Depression					.82 (.82)	0.01	0.96 (.78)	0.02

Table S13 Continued

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Verbal ability							-0.33 (.02) ***	-0.17***
Constant	32.61 (.32) ***		77.18 (8.19) ***		81.25 (8.20) ***		104.44 (7.55) ***	
R-squared	0.02		0.03		0.07		0.09	

*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 S14

Regression Estimates [coefficients (SE) & standardised coefficients] of Internalising Problem Group Membership on SWM Strategy

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Internalising Behaviours (Ref: No risk)								
Deteriorating	.91 (.30) **	0.04**	.80 (.29) **	0.03**	.54 (.29)	0.02	.45 (.29)	0.02
Low risk	.73 (.14) ***	0.06***	.75 (.14) ***	0.06***	.51 (.14) ***	0.04***	.43 (.14) **	0.03**
High risk	1.17 (.19) ***	0.08***	1.16 (.19) ***	0.08***	.57 (.18) **	0.04**	.36 (.18) *	0.02*
Age at Sweep 5			-.08 (.02) ***	-0.06***	-.09 (.02) ***	-0.06***	-.12 (.02) ***	-0.08***
Gender (Ref: Male)								
Female			.12 (.14)	0.02	.15 (.14)	0.01	.07 (.14)	0.01

Table S14 Continued

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Poverty					.98 (.20) ***	0.06***	.59 (.20) **	0.04**
Ethnicity (Ref: White)								
Mixed					-.22 (.40)	-0.01	-.12 (.40)	-0.004
Indian					-.41 (.50)	-0.01	-.07 (.48)	-0.002
Pakistani and Bangladeshi					.50 (.34)	0.02	.40 (.36)	0.01
Black or Black British					.90 (.32) **	0.03**	1.03 (.30) **	0.03**
Other (Inc Chinese)					-.67 (.77)	-0.01	-.73 (.79)	-0.01
Maternal Education								
Has 1st degree					-1.93 (.19) ***	-0.12***	-1.59 (.21) ***	-0.10***
Maternal Depression					.31 (.22)	0.02	.35 (.22)	0.02
Verbal ability							-.08 (.01) ***	-0.13***
Constant	33.73 (.10) ***		44.26 (2.46) ***		46.07 (2.48) ***		54.88 (2.37) ***	
R-squared	0.01		0.01		0.04		0.05	

*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 S15

Regression Estimates [coefficients (SE) & standardised coefficients] of Conduct Problem Group Membership on SWM Total Errors

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Conduct Problems (Ref: Early childhood limited)								
Deteriorating	2.46 (1.12) *	0.02*	2.09 (1.12)	0.02	.87 (1.10)	0.01	.27 (1.07)	0.003
Improving	3.94 (.56) ***	0.09***	3.90 (.56) ***	0.08***	2.29 (.60) ***	0.05***	1.59 (.56) **	0.03**
High risk	7.73 (.65) ***	0.14***	7.44 (.63) ***	0.14***	5.00 (.73) ***	0.09***	3.88 (.68) ***	0.07***
Age at Sweep 5			-.32 (.06) ***	-0.07***	-.36 (.06) ***	-0.08***	-.38 (.05) ***	-0.08***
Gender (Ref: Male)								
Female			-.70 (.39)	-0.02	-.79 (.40) *	-0.02*	-1.09 (.39) **	-0.03**
Poverty					5.76 (.67) ***	0.11***	4.26 (.70) ***	0.08***
Ethnicity (Ref: White)								
Mixed					1.29 (1.48)	0.01	1.71 (1.46)	0.02
Indian					-.17 (1.72)	-0.001	.87 (1.69)	0.01
Pakistani and Bangladeshi					1.16 (1.08)	0.01	.67 (1.23)	0.01
Black or Black British					5.50 (1.64) **	0.05**	6.22 (1.58) ***	0.06***
Other (Inc Chinese)					-2.38 (2.27)	-0.01	-2.34 (2.25)	-0.01
Maternal Education								
Has 1st degree					-6.23 (.56) ***	-0.12***	-4.90 (.59) ***	-0.10***
Maternal Depression					1.14 (.83)	0.02	1.17 (.78)	0.02
Verbal ability							-.33 (.02) ***	-0.17***

Table S15 Continued

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Constant	33.32 (.32) ***		76.37 (8.23) ***		80.93 (8.23) ***		104.23 (7.58) ***	
R-squared	0.02		0.03		0.07		0.09	

*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 S16

Regression Estimates [coefficients (SE) & standardised coefficients] of Conduct Problem Group Membership on SWM Strategy

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Conduct Problems (Ref: Early childhood limited)								
Deteriorating	1.00 (.30) **	0.03**	.92 (.29) **	0.03**	.55 (.29)	0.02	.36 (.29)	0.01
Improving	.83 (.15) ***	0.06***	.84 (.15) ***	0.06***	.43 (.17) **	0.03**	.32 (.16) *	0.02*
High risk	1.52 (.22) ***	0.09***	1.51 (.21) ***	0.09***	1.01 (.23) ***	0.06***	.85 (.20) ***	0.05***
Age at Sweep 5			-.08 (.02) ***	-0.05***	-.09 (.02) ***	-0.06***	-.12 (.02) ***	-0.08***
Gender (Ref: Male)								
Female			.20 (.14)	0.02	.20 (.14)	0.02	.11 (.14)	0.01
Poverty					.93 (.19) ***	0.06***	.55 (.20) **	0.04**
Ethnicity (Ref: White)								
Mixed					-.24 (.40)	-0.01	-.16 (.40)	-0.005
Indian					-.29 (.50)	-0.01	.02 (.48)	0.0004
Pakistani and Bangladeshi					.64 (.34)	0.02	.50 (.36)	0.02

Table S16 Continued

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Black or Black British					.94 (.32) **	0.03**	1.05 (.30) **	0.03**
Other (Inc Chinese)					-.65 (.76)	-0.01	-.73 (.78)	-0.01
Maternal Education								
Has 1st degree					-1.91 (.19) ***	-0.12***	-1.58 (.22) ***	-0.10***
Maternal Depression					.28 (.23)	0.02	.31 (.23)	0.02
Verbal ability							-.08 (.01) ***	-0.13***
Constant	33.81 (.09) ***		43.88 (2.42) ***		45.83 (2.45) ***		54.62 (2.34) ***	
R-squared	0.01		0.01		0.04		0.06	

*p< 0.05; **p<0.01; ***p<0.001; CI = confidence interval; LL = lower limit; UL = upper limit.
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 S17

Regression Estimates [coefficients (SE) & standardised coefficients] of Hyperactivity / inattention Group Membership on SWM Total Errors

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Hyperactivity / inattention (Ref: Typically developing)								
Deteriorating	6.11 (.70) ***	0.09***	5.91 (.71) ***	0.09***	4.73 (.71) ***	0.07***	3.90 (.71) ***	0.06***
Improving	6.02 (.60) ***	0.12***	5.99 (.60) ***	0.12***	3.93 (.61) ***	0.08***	3.16 (.59) ***	0.06***
High risk	11.12 (.89) ***	0.16***	10.89 (.87) ***	0.15***	8.62 (1.00) ***	0.12***	6.58 (.84) ***	0.09***
Age at Sweep 5			-.32 (.06) ***	-0.07***	-.35 (.06) ***	-0.08***	-.38 (.05) ***	-0.08***
Gender (Ref: Male)								
Female			-.25 (.39)	-0.007	-.36 (.40)	-0.01	-.74 (.39)	-0.02
Poverty					5.71 (.66) ***	0.11***	4.26 (.67) ***	0.08***
Ethnicity (Ref: White)								
Mixed					1.21 (1.47)	0.01	1.59 (1.45)	0.01
Indian					-.28 (1.69)	-0.002	.70 (1.68)	0.005
Pakistani and Bangladeshi					1.11 (1.18)	0.01	.70 (1.32)	0.007
Black or Black British					5.82 (1.65) ***	0.05***	6.49 (1.57) ***	0.06***
Other (Inc Chinese)					-1.68 (2.26)	-0.01	-1.74 (2.22)	-0.01
Maternal Education								
Has 1st degree					-6.00 (.56) ***	-0.12***	-4.77 (.58) ***	-0.10***
Maternal Depression					.66 (.81)	0.01	.82 (.77)	0.01
Verbal ability							-.31 (.02) ***	-0.16***
Constant	32.98 (.29) ***		75.21 (8.07) ***		79.27 (7.99) ***		101.92 (7.56) ***	
R-squared	0.04		0.04		0.08		0.10	

*p< 0.05; **p<0.01; ***p<0.001; CI = confidence interval; LL = lower limit; UL = upper limit.
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 S18

Regression Estimates [coefficients (SE) & standardised coefficients] of Hyperactivity / inattention Group Membership on SWM Strategy

	Model 1		Model 2		Model 3		Model 4	
	B (SE)	**β**	**B (SE)**	**β**	**B (SE)**	**β**	**B (SE)**	**β**
Hyperactivity / inattention (Ref: Typically developing)								
Deteriorating	1.19 (.22) ***	0.06***	1.18 (.22) ***	0.06***	.92 (.23) ***	0.05***	.70 (.23) **	0.03**
Improving	1.39 (.18) ***	0.09***	1.42 (.18) ***	0.09***	.92 (.19) ***	0.06***	.72 (.18) ***	0.05***
High risk	1.84 (.24) ***	0.08***	1.88 (.24) ***	0.08***	1.27 (.26) ***	0.06***	1.16 (.24) ***	0.05***
Age at Sweep 5			-.08 (.02) ***	-0.05***	-.09 (.02) ***	-0.06***	-.12 (.02) ***	-0.08***
Gender (Ref: Male)								
Female			.29 (.13) *	0.03*	.27 (.14) *	0.02*	.18 (.14)	0.02
Poverty					.90 (.20) ***	0.06***	.53 (.20) **	0.03**
Ethnicity (Ref: White)								
Mixed					-.19 (.40)	-0.01	-.11 (.40)	-0.003
Indian					-.33 (.49)	-0.01	-.03 (.48)	-0.001
Pakistani and Bangladeshi					.59 (.35)	0.02	.47 (.37)	0.02
Black or Black British					1.00 (.31) **	0.03**	1.09 (.30) ***	0.03***
Other (Inc Chinese)					-.52 (.76)	-0.01	-.60 (.78)	-0.01
Maternal Education								
Has 1st degree					-1.88 (.19) ***	-0.12***	-1.57 (.21) ***	-0.10***
Maternal Depression					.19 (.23)	0.01	.23 (.23)	0.01
Verbal ability							-.08 (.01) ***	-0.13***
Constant	33.76 (.08) ***		43.68 (2.45) ***		45.51 (2.46) ***		54.09 (2.32) ***	
R-squared	0.01		0.02		0.04		0.06	

*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)