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Children's mathematical achievement and how it relates to working memory, test anxiety and self-regulation: A person-centred approach

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Abstract

Meeting the challenges of teaching to all individuals requires a multifaceted approach, especially from the Swedish standpoint of inclusive education for all pupils. In the context of applied standards for receiving special educational provision, the present paper strives to shed light on the scope of novel indicators which can accommodate pupils' different needs. Founded on three established and robust psycho-educational concepts – working memory, test anxiety and self-regulation – all of which are important for educational, social, emotional and behavioural development, the present study examines those concepts in terms of profiles and their relations to mathematical achievement. A battery of tests was completed by 624 children between the ages of 8 and 10 to assess their working memory, test anxiety, self-regulation, and mathematical achievement. Person-centred analyses confirmed the negative academic outcomes associated with the aforementioned variables but also revealed individual variations that warrant attention. Further, pupils labelled with an 'At-risk' profile were more likely to achieve low Maths scores, compared to pupils with an 'In-vigour' profile. An implication for special educational provision is discussed, and practical suggestions are provided.

Keywords: working memory, test anxiety, self-regulation, mathematics, primary-school level

Introduction

While the formal education of teachers provides them with subject knowledge and skills as well as guiding instructional principles needed for developing academic competence (see Socialstyrelsen, 2009; Vingsle, 2014), many pupil-related factors grounded in psychological and neurocognitive knowledge that may hinder pupils' access to the course syllabus, or growth to the maximum extent possible, are not being addressed (see Karpicke and Grimaldi, 2012; Rohrer and Pashler, 2010; Weems et al. 2014), such as emotional-cognitive interference that equally puts those pupils at risk of future serious problems (see Collins, Woolfson and Durkin, 2013; Murphy and Fonagy, 2013).

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The Swedish Education Act from 2011 (SFS 2010:800) prescribes that if a pupil will not achieve the minimum knowledge goal *or* if the pupil has additional needs in their school situation, special educational provision shall be given within general basic compulsory classes. In keeping with this, Pupil Health Care should support pupils' entitlements to progress and development, and special educators have an important role in this connection (Socialstyrelsen, Skolverket, 2014). Yet, the recently released directives of the Pupil Health Care Act in Sweden lack substantial strategies. That leaves ample opportunity for growth in this area.

Several personal competencies linked to social, emotional and behavioural developmental factors are associated with academic learning and achievement; conversely, difficulties with such competencies correlate with school problems like underachievement and school dropout (Allison, Nativio, Mitchell, Ren and Yuhasz, 2014; MacCabe et al. 2013). There is convincing evidence of a two-way relationship between underachievement and social, emotional and behavioural difficulties (Gustafsson et al. 2010; see Sonnby, 2014). Children suffering from school problems often have externalised or internalised problems or overall mental ill-health that are related to their learning difficulties. Put the other way around, mental health problems are further exacerbated by academic failures (Masten, Desjardins, Mccormick, I-Cuni Kuo and Long, 2010; see Moilanen, Shaw and Maxwell, 2010).

Several studies have shown that both the academic and mental needs of children must ultimately be addressed so as to allow all pupils access to the curriculum and provide a benign academic learning experience (Stornes and Bru, 2011), while also assisting with children's well-being and development (Akinsola and Nwajei, 2013; Sullivan and Sadeh, 2014).

Hence, a growing corpus of research relates people's ability to function within the education system to areas such as cognitive processing and social functioning (e.g., Owens, Stevenson, Hadwin and Norgate, 2014; Vilgis, Chen, Silk, Cunnington and Vance, 2014). Accordingly, it is well established that working memory (WM) is a strong predictor of academic achievement (Ullman, Almeida and Klingberg, 2014) and that it is intimately associated with self-regulation (SR) (Davidson and McEwen, 2012); both also lead to resilience to elevated levels of anxiety and social dysfunction (Hrbáčková and Vávroivá, 2014; Ullman et al. 2014). With regard to emotional-cognitive processing, test anxiety (TA) can be a source of behaviour bias (Ganley and Vasilyeva, 2014), with SR possibly blocking the intrusion (Putwain and Daly, 2013; Hayes and Embretson, 2013) as a function of WM and the executive control system (Halse, 2014). On the other hand, WM and TA compete for the same cognitive resources and such competition is potentially draining the resources available for SR to negotiate TA.

Nonetheless, in the majority of previous studies only individual variables were studied, whereas less is known about their combined associations or if these combinations comprise critical differences in risk profiles (Moilanen et al. 2010; see

Van Dam Gros, Earleywine and Antony, 2013). In addition, variable-centred analyses are typically used (see Putwain and Daly, 2013), while few studies adopt a person-oriented approach and examine the different conditions of (e.g., combinations of variables) pupils' achievements (see Eisenberg, Spinrad and Eggum, 2010). The impact on children varies and, despite recognised risks with poor SR capacity and elevated anxiety, not all are equally afflicted, or even distracted (Galla and Wood, 2012; Hayes and Embretson, 2013).

In the present study, we investigate WM, TA and SR in terms of profiles, and their interdependent relations and significance for mathematical achievement.

An understanding of the nature of emotional-cognitive factors and relations is of particular concern because insufficient SR (Gullone and Taffle, 2012), poor working memory capacity (WMC) (Ullman et al. 2014) and high levels of TA (Fentz et al. 2013) are related to learning difficulties. It is also important to note that some pupils suffering from aversive behavioural and emotional traits are attending school without their difficulties being recognised or help being provided (see Cullinan and Epstein, 2013). Hence, a non-school failure seldom attracts the attention of special educators, and rarely is direct formal support given for intervention if a pupil is perceived to have access to the curriculum (Cullinan and Epstein, 2013; Gustafsson et al. 2010). Thus, pupils are missed due to their 'good enough' test scores and likely do not create any notable concerns. However, in the long run, pupils scoring well in exams and making a great deal of effort for good academic achievement may be putting their health at risk (e.g., leading to low affective well-being, stress and hopelessness) (Eum and Rice, 2011; Roslander, 2013). Unfortunately, regarding children there is a paucity of research directly related to both the interplay between TA, SR and WM in relation to academic achievement, and the impact of salient versus masked variables. This statement is underscored by an OECD (2013) report (also see Skolinspektionen, 2014).

Accordingly, 'at-risk' pupils are traditionally only defined by low achievement scores or the failure to pass any levels. But there is more to education than the mere absence of failure. The present study thus impartially investigates pupils who score lowly in maths together with pupils who do not score lowly in maths but who we argue nonetheless warrant provision because their absence of failure will probably not trigger any special educational provision.

Emotional-cognitive issues in children

Around 5%–7% of preschool children and 10% of school children in Sweden have developmental-related disabilities (see Fernell, Landegren and Gillberg, 2012). Recent global prevalence figures for children under the age of 18 indicate 10%–20% (see Sonnby, 2014). In Sweden, mental problems are the third most common reason for ill-health in ages 0 to 18 years and it is estimated that 30% have a child psychiatric diagnosis (Sonnby, 2013).

Anxiety disorders belong to the most prevalent types of psychopathology during childhood, occurring in magnitudes of up to 10%–15%, and showing an increased developmental trend (Kozina, 2014; Weems et al. 2014), frequently leading to disease and mental disability in adulthood (Patton et al. 2014).

Test anxiety. Childhood TA is a subtype of anxiety, comprising the same omnipresent nature and typical SR styles, e.g. cognitive depletion, self-defeating coping, or attentional bias (Zeidner and Matthews, 2005; Van Dam et al. 2013). TA assessments are indirect indicators of psychopathological anxiety symptoms and suggested to be of potential clinical use (Van Dam et al. 2013; Weems et al. 2014). TA is thought to be one of the most common sources of emotional distress in contemporary society, greatly impairing academic performance when it occurs at excessive levels (Harpell and Andrews, 2013; Nie, Lau and Liau, 2011).

TA not only affects a pupil's ability to perform well academically, but is also associated with impairments of socio-emotional and behavioural functioning and development, as well as a pupil's self-worth, self-confidence, self-esteem, school-related motivation, concept of school, career advancement etc. (Carter, Williams and Silverman, 2008). In children, TA has been shown to co-occur with formally diagnosable anxiety disorders as defined in the Diagnostic and Statistical Manual of Mental Disorders-IV (DSM-IV), i.e., Social Anxiety Disorder (SAD), Generalised Anxiety Disorder (GAD) (Bögels et al. 2010; also see Van Dam et al. 2013), and depression (Owens, Stevenson, Hadwin and Norgate, 2012).

TA is predominantly considered to induce physiological (producing sustained hyper-arousal), emotional (including bodily symptoms and tension) and behavioural (referring to auto-manipulative, object-manipulative and inattentive off-task behaviours) responses, as well as a strain on the cognitive systems by inducing worries and irrelevant thoughts regarding a pending exam or evaluation (see Carter et al. 2008). The cognitive factor is suggested to directly impact performance, while the emotional component appears to be indirectly related to test performance (Cassady, 2009; Hayes and Embretson, 2013). The emotional component seems to thus trigger SR strategies which, in turn, facilitate or negatively influence performance (Schutz, Distefano, Benson and Davis, 2004).

Self-regulation. Although there is no description or provision for the diagnosis of weak SR capacity, deficient SR is a pivotal symptom implicated in several developmental disorders (see Gullone and Taffle, 2012; Rizzo, Steinhausen and Drechsler, 2010) and in psychopathological conditions (Eisenberg et al. 2010; Gullone and Taffle, 2012). Insufficient SR is associated with negative developmental trajectories, such as increased risk for adult anxiety, depressive and borderline personality disorders, criminal behaviours, substance use problems, anorexia nervosa, and lower workforce participation and low income (see Andersson, 2012; Enebrink, Björnsdotter and Ghaderi, 2013; Rhodes, 2013). In individuals with depressive disorders lacking emotional regulation, key regions in the prefrontal regions have been shown to play an important role, regions that sub-serve the WM network (Vilgis et al. 2014). Several studies (e.g., Ginsburg et al. 2014; Scarpa and Reyes, 2011) have suggested that SR is critical to the development and maintenance of healthy emotional functioning and, since SR is associated with the WM brain network, measures of WM and its executive function are of particular interest.

Moreover, studies of children who have SR difficulties, externalise problems and have hyperactivity/inattention are also over-representative of learning disabilities, poor grades and low grade retention (see Haskett, Stelter, Proffit and Nice, 2012; see Raver, 2012). Insufficient SR is even suggested to be the most common cause of primary-grade pupils' school difficulties (see Rizzo et al. 2010).

Self-regulatory mechanisms are an individual's immediate response to elevated levels of arousal and are often described as connected to the executive functions of WM (Halse, 2014; Hofmann, Schmeichel and Baddeley, 2012; Knouse, Feldman and Blevins, 2014). SR covers a number of responses (short and long term) that aim to reduce tension and is linked to the autonomic nervous system. By evaluating, inhibiting, monitoring or modifying internal feeling states and physiological processes, as well as the behavioural concomitants of emotion, individuals continuously respond to, adapt to and comply with the ongoing demands of experience which allow the inhibition of behaviour (Andersson, 2012; Florez, 2011). SR acts as a suppressor in the relationship between TA and e.g. academic performance (Hayes and Embretson, 2013; Weis, Heikamp and Trommsdorff, 2013). In demanding situations such as academic testing, emotional regulation involves task-focusing, emotion-focusing and cognitive-appraising processes (Schutz et al. 2004). To self-direct focus during testing whilst being in an affective state pupils cope by using goal-directed self-talk. Pupils' perceptions of the task mean a disengagement from the task; instead, they have feelings and thoughts about their performance as well as potential reasons for it. This interferes or facilitates performance as the level of TA either increases or decreases (Toering et al. 2012).

Working memory. The term working memory refers to a cognitive concept (Baddeley, 1992) and consists of several interacting brain processes (Heister et al. 2013). Baddeley's widely-accepted model of WM consists of a central executive which is responsible for the control and regulation of cognitive processes (Baddeley, 1992). The central executive is controlling three separable but interacting subsystems: the phonological loop, the visuo-spatial sketchpad and the episodic buffer (Baddeley, 2000). The central executive is also intimately related to the regulation of goal-oriented behaviour such as planning, initiating, shifting and inhibition (Miyake et al. 2000). It is a system that can hold multiple items of passing information within the mind, irrespective of where they are to be manipulated, and has repeatedly been identified as a significant predictor of school performance and is often used as a proxy for academic potential (Ullman et al. 2014; Witt, 2011) and intelligence (Chein, Moore, and Conway, 2011). Several studies investigating WM have found that there are relative large individual differences in WMC. Hence, people differ in their ability to control attention and process concurrent information (Engle and Kane, 2004).

WM, TA, SR: Relevance for academic achievement

WM and TA. As WM is not a fixed, but an active, response system using the senses, it is also believed to be sensitive to, and interrupted by, competitive and/or negative stimuli and emotions, thereby losing stored (old and new) facts (Alloway, Gathercole and Pickering, 2006; Purves et al. 2012). Raised levels of worry that impinge on the central executive processes and high levels of anxiety are thought to form the link between emotional distress and academic underachievement in children (Owens et al. 2012; Vilgis et al. 2014). The point where 'normal' worry goes beyond an 'unpleasant state' and adversely affects academic performance varies from pupil to pupil (Akinsola and Nwajei, 2013; Schwabe, Joëls, Roozendaal, Wolf and Oitzl, 2012). Various theories of childhood anxiety consider that cognitive distortions drive the development and maintenance of anxiety (In-Albon, Klein, Rinck, Becker and Schneider, 2008; Muris and Field, 2008). In line with this, severe stress putatively suppresses the development of WM (Halse, 2014).

In an aversive somatic and emotional state (e.g., that which accompanies high anxiety), which occurs naturally during the process of confronting fear, the individual copes with worrisome thoughts, negative feelings and physical reactions to avoid suffering (Behar, DiMarco, Hekler, Mohlman and Staples, 2009; Cohen, Young, Gibb, Hankin and Abela, 2014).

WM and SR. Both WM and SR are regarded as systems that have limited resources, which means they compete for the same resources (Hofmann, Gschwendner, Friese, Wiers and Schmitt, 2012). For example, stress that adds a load to cognitive processing may lead to insufficient emotional control or, in other words, stress may lead to resource depletion because stress (e.g., intrusive thoughts) depletes the WM resources which should be available for the self-regulatory process (e.g., Beilock, Rydell and McConnell, 2007). Hence, WM supports goal-oriented behaviour by helping an individual to resist stimulus distractors through the allocation of resources to self-regulation (Hofmann et al. 2008; Fries et al. 2010). In this respect, it is important to note that individuals with high WMC spans are better at suppressing their intrusive thoughts (e.g., Brewin and Smart, 2005). On the other hand, for individuals with low WMC it is closer between impulsive and/or intrusive processes and behaviour; hence, the ability to maintain attentional focus is limited. For instance, Hofmann et al. (2008, study 2) showed that when individuals with lower WMC were exposed to tempting sweets they were more prone to act according to their affective response (I want to eat the candy) than individuals with higher WMC.

In summary, with regard to TA and SR there is an intimate relationship with WM. Hence, low WM leads to automatic impulsive processing and subsequent affective and behavioural responses. In certain conditions (high cognitive load) or situations (high-stakes tests), SR can be temporally impaired (Hofmann et al. 2012). Over time, poor WM (Ullman et al. 2014), childhood anxiety (Scoffham and Barnes, 2011) and insufficient SR (Hrbáčková and Vávroivá, 2014) are potential risk factors predisposing academic failure and even mental ill-health in adulthood.

Aim

The present study extends previous findings on emotional-cognitive issues in academic performance by investigating profiles of WM, TA and SR, and their different relations to, and significance for, mathematical achievement in young pupils. We argue that studying the basic cognitive capacities involved in the learning process, and how the associated emotions and behaviours are affected in relation to available capacity, can inform teachers about pupils' scholastic aptitude, and what their strengths and weaknesses are (see Burnett, Thompson, Bird and Blakemore, 2011; Hayes and Embretson, 2013; Wu and Chu, 2012; for similar arguments). Therefore, our specific questions are:

q1) What kind of emotional-cognitive profiles of WM, TA and SR can be identified among grade 3 pupils?
q2) How are these emotional-cognitive profiles related to mathematical achievement?

Method

Instruments

In this study, the results of the national test in mathematics for grade 3 were used. National tests are mandatory for Swedish pupils in grades 3, 6 and 9; with Swedish and Mathematics as recurrent subjects assessed. Regarding Swedish in grade 3, several of the partial tests are only judged holistically with 'Pass' or 'Not Pass'. In addition, since mathematical achievement per se has a strong positive effect on pupils' well-being in all ages and around the world (Mulcahy, Krezmien and Maccini, 2014), and among school subjects seems to hold a primary position in requiring extensive cognitive demands (Hayes and Embretson, 2013), and in causing more stress in performance situations (von der Embse and Hasson, 2012), studying emotional-cognitive interference through the lens of mathematical achievement seems convincing. Individual differences in WM have also been demonstrated as a potent predictor of mathematical development (Nyroos and Hörnqvist-Wiklund, 2012) stressing the importance of mathematical ability.

Working memory test. WM was assessed using three computerised group-adjusted tasks representing both content domains of WM (verbal and spatial), and both functional aspects (storage in the context of processing and potential trade-offs between these). Each task primarily evaluated one of the three components of the Baddeley and Hitch (1974) model: the central executive (Operation Span), the phonological loop (Digit Span), and the visuospatial sketchpad (Block Span). The reliability coefficient of the WM test was $\alpha = .72$. The correlation coefficients are shown in Table 1, and descriptive statistics in Table 2.

Table 1. Correlation coefficients for WMC-, CTAS-, SelfReg-, and Math-total scores

	WMC	CTAS	SelfReg	Math scores
WMC	1	−.153**	.274**	.397**
CTAS		1	−.506**	−.257**
SelfReg			1	.288**
Math scores				1

Pearson Correlation 2-tailed **$p < .001$

Operation Span. The Operation Span (Ospan) task devised by Turner and Engle (1989) is one of the most valid and reliable measures of WMC. It is ecologically valid, predictive of a range of cognitive abilities, and consistent with the definition of WM proposed by Baddeley (Chein et al. 2011). It involves the recall of a short series of interleaved words, and the solving of simple equations, i.e. participants have to perform mathematical operations while simultaneously retaining words/letters in their short-term memory. The Ospan task is available as an automated version where words are replaced with letters (Unsworth, Heitz, Schrock and Engle, 2005), and has been used with slight variations to reflect new developments (e.g., Elliot and Conway, 2005; Lépine, Bernardin and Barrouuillet, 2005). The Ospan task used in this study was only slightly modified. Since there are no language-specific components in Ospan and it is invariant across languages and cultures (Lewandowsky, Oberauer, Yang and Ecker, 2010), constructing a Swedish version was relatively straightforward. The same set of high-frequency letters in the operation-letter strings was used, while the addition was the only arithmetic operation used without tens transition (i.e., the sum always fell in the range of 3 to 9), and using the integers 2 to 9. The total number of letters to be recalled increased with higher level tests. The task began at level two with two sequences, then proceeded to the next level as long as two sets in a row were correctly answered. Thus, there was no predefined highest level but the span score ranged from zero to the individual's highest level.

The ‘operation span’ is then defined as the maximum number of letters that are correctly recalled in the correct order. Thus, the raw score for Ospan is the number of correct trials, with (in theory) an unlimited maximum (minimum 0).

Digit Span. Digit Span is usually administrated orally as an expert-child task. Numbers from 1 to 9 are displayed on a screen at the rate of one per second. The pupil is then instructed to recall the numbers in the correct order, both forwards and backwards, by pressing the corresponding number on a keyboard. The test stops when the pupil fails to repeat two tests successfully at any particular span length. The raw score for Digit Span Forward is the number of correct trials, with (in theory) an unlimited maximum (minimum 4). The raw score for Digit Span Backward has an (in theory) an unlimited maximum (minimum 4).

Block Span. The Block Span (or Corsi block-tapping test) exists as an orally-administrated version, an expert-child task, and a computer-based task. This test consists of 16 green blocks on a screen, arranged as a four-by-four square, with one block at a time randomly flashed red at the rate of one per second. The child is instructed to observe the sequence of blocks displayed red, and then attempt to repeat the sequence by clicking the mouse on a different square with 16 green blocks. First, they repeat the order forwards, and then in reverse. Two different sequences are presented for each span length. The test continues until the child fails to repeat both tests at any particular span length. The raw score for both Block Span Forward and Block Span Backward is the number of correct trials (4 up to an unlimited maximum).

Self-reporting questionnaires. The Children’s Test Anxiety Scale (CTAS: Wren and Benson, 2004) is only available in English as a paper and pencil scale. The Self-rating of Self-regulatory Function (SelfReg) (Rizzo et al. 2010) was originally computer-based, and available in German and Danish, in a boy’s and a girl’s version. The items in the CTAS and SelfReg were slightly adapted to Swedish schooling, which ultimately meant only small adjustments to some statements. Accordingly, the CTAS and SelfReg were back-translated into Swedish, the CTAS adapted for use on a computer, and the SelfReg adapted for group sessions. Clicker technology was used to administer the CTAS and SelfReg so the CTAS was transferred and slightly modified to function with PowerPoint, and the response system.

CTAS. TA was assessed using the CTAS (Wren and Benson, 2004), which is designed for use in measuring the construct of generalised TA in pupils from culturally diverse groups from grades 3 to 6. Several researchers have reported that the CTAS has good psychometric properties (e.g., Weissman, Antioro and Chu, 2008; Zeidner, 2007). Wren and Benson (2004) reported that it exhibited good internal consistency for the original sample ($\alpha = .92$) and for their cross-validation sample ($\alpha = .92$).

In the present study, internal consistency among the items was α = .89. The CTAS asks pupils how they feel when thinking about tests, and measures three forms of anxiety responses relating to a pupil's thoughts, autonomic reactions, and off-task behaviours. Wren and Benson (2004) believe TA in children to be a situation-specific trait that has cognitive effects, and induces somatic symptoms and test-irrelevant behaviours. The 30 items relating to test anxiety have a four-step scoring format with the following self-response categories: 1 = 'almost never', 2 = 'some of the time', 3 = 'most of the time', and 4 = 'almost always'. An individual's overall score is equal to the sum of their responses to each item of the instrument. Scores on the CTAS range from 30 to 120. So far, the CTAS is the only scale available for assessing TA in children in this age group.

SelfReg. The SelfReg (Rizzo et al. 2010) is a new computer-based scale for assessing the SR skills of children aged 8 to 10 years. It has been shown to be valid and sensitive for the assessment of metacognitive knowledge of SR skills in school children.

The construct of SR in the SelfReg is in accordance with Baddeley's (2000) WM model where WM operations are one (of several) executive functions with a connection to self-regulatory mechanisms, such as regulation of effects and shielding during interference or distractions (elevated TA) (Hofmann et al. 2012).

The scale was developed for use with children with functional or dysfunctional SR, and for use in an educational or clinical setting. The scale consists of 28 items with age-appropriate content divided into two main scales encompassing behavioural/emotional regulation (emotion, motivation, motor activity, inhibition), and cognitive regulation (speed of processing, distractibility, sustained attention). For each item, five responses graded on a Likert-type scale are possible (1 = 'very often', 2 = 'most of the time', 3 = 'sometimes', 4 = 'rarely', and 5 = 'never'). An individual's overall score is equal to the sum of their responses to each item of the instrument. Scores on the SelfReg range from 28 to 140. In a sample of typically developing children, Rizzo et al. (2010) reported α = .92 for the SelfReg. In the present study, the reliability coefficient among the items was α = .84. In the SelfReg children are asked to judge their SR skills in different situations by relating their own behaviour to that of other children.

Table 2. Descriptive statistics for WMC-, CTAS-, SelfReg-, and Math-total scores

	Mean	sd.	Min	Max
WMC	17.13	3.02	8	26
CTAS	51.64	12.94	30	112
SelfReg	107.55	15.25	53	140
Math	61.21	7.77	6	71

Participants and settings

This study is based on a sample of 624 pupils from 39 grade 3 classes from five Swedish municipalities (varying geography: covering the countryside, hinterland, urban areas and cities; and demographic differences: inhabitants, average age, in/emigrations, employment; and different school forms: private and public schools) within one region. Demographic statistics are presented in Table 3. There were 320 girls and 304 boys, and the mean age was 9.3 years (range 104–128 months). No exclusion criteria were set up, and 96.6% of all pupils asked consented to participate. The head teacher and teachers in the respective schools were contacted and asked to participate. The study was approved by the Region Ethical Review Board, and informed consent from parents was obtained.

Table 3. Demographic statistics in proportion for participating schools

	Mean	sd.	Min	Max
Pupils with Immigrant background	6.3	5.5	0	21
Parents with Post-secondary education	60.8	17.8	0	85
Pupils with Other mother tongue	27.7	4.7	0	19
Teachers with Higher teacher education	94.5	4.5	82	100

Procedure

The pupils were asked to complete the two scales during an ordinary 45-minute classroom period. They were administered on different days, starting with the CTAS, with a teacher present. In order to ensure optimal completion of the questionnaires, the research assistant read each question aloud. The pupils completed the WM test in a separate room in groups of three. It started with Ospan followed by Block Span Forwards then Digit Span Forwards, Block Span Backwards and, finally, Digit Span Backwards. In order to ensure that all pupils understood the WM tasks, the first set at level two were 'looped' until two consecutive tests were passed. If the 'looping' was not sufficient an audible warning alerted the researchers that the pupil needed more guidance. However, some pupils were not able to manage the task (they scored 0) but were allowed to continue to the next task (i.e., a researcher manually set up the next set of tests).

The data were collected by two trained assistants, and took place at the schools over a 4-month period. The WM task took approximately 20–30 minutes for each group, and the CTAS and the SelfReg approximately 20–30 minutes for each class. The administration of the WM test was altered to fit into the school day, and in consultation with the teacher.

Analytic strategy

The basic assumption underlying the analyses builds on the understanding of the normal distribution of risk; the vast majority of the population falls into the main area of the distribution curves (at 'low or medium risk') and individuals at 'high risk' at the tails of the distribution curve. The proportion of people defined as 'mentally ill' is thus directly related to the population's mean level of behavioural problems (Rose, 2001; 2011).

In order to identify emotional-cognitive profiles, the distributional properties of the WM, TA and SR measures were investigated. Subsequently, in the current study scores less than minus 1 standard deviation and above plus 1 standard deviation, respectively, from the total mean scores were applied to the WM test, CTAS and SelfReg (following e.g., Mononen, Auino and Koponen, 2014; see Table 4), and pupils designated the 'At-risk' profile, 'In-vigour' profile (vigour is a commonly used term in 'positive psychology' and refers to e.g. health, well-being and mental resilience: see e.g., Diez-Pinol, Dolan, Sierra, and Cannings, 2008; Tuominen-Soini, Samela-Aro, and Niemivirta, 2012), 'Mixed' profile (both 'At-risk' and 'In-vigour' profiles), or 'None' profile (neither the 'At-risk' nor 'In-vigour' profiles) (also see Cullinan and Epstein, 2013). (Note, 1.0–2.5 sd. below/above the population mean for age is suggested in DSM-5: APA, 2013). Consistent with this tenet, and to aid interpretation of the result in an educational context, Maths scores were designated as high (+1 sd. above maths mean scores) and low (-1 sd. below maths mean scores), respectively. The relations between emotional-cognitive profiles and maths achievement were investigated with an independent samples chi-square test (χ^2). In a cross-tabulation the observed frequencies were compared to the expected frequencies, and the χ^2 test determined whether the difference was statistically significant.

Result

Table 4. Frequencies and proportion of High- (H) and Low- (L) Math, WMC, TA, and SR

	Hmath	Lmath	Hwmc	Lwmc	Hta	Lta	Hsr	Lsr
n	52	72	83	114	88	81	107	94
%	8.3	11.5	13.3	18.3	14.1	13.0	17.1	15.1

Profiles of WM, TA and SR

Overall, the most frequent condition within the 'At-risk' profile was low WMC (18.3%), followed by low SR (15.1%), and high TA (14.1%) (Table 4). Of all profiles comprising low WMC ($n = 99$), 31 cases (31%) also were observed with low Maths scores; with the corresponding number for profiles comprising: high TA (17 of 61 cases, 28%), and low SR (20 of 80 cases, 20%). Regarding the 'In-vigour' profile, a high SR (17.1%) was the variable most commonly reported, followed by high WM (13.3%) and low TA (13.0%).

Across the whole sample, 190 pupils (30%) were observed with one or more set of the 'At-risk' profile, whereas 161 pupils (26%) showed the 'In-vigour' profile. Further, 8% of the whole sample ($n = 52$) was identified with at least two 'At-risk' components, whereas 9% ($n = 54$) had at least two 'In-vigour' components. Thirty-four pupils (5%) had a 'Mixed' profile, i.e. both 'At-risk'- and 'In-vigour' sets, and 239 pupils (38%) were designated with the 'None' profile. Common to the three pupils within the 'Mixed' profile group who also had low Maths scores was low WMC, while low SR was common to the three pupils with a 'Mixed' profile who had high Maths scores.

Dominating the 'At-risk' profile were single factors, and here low WMC stood out ($n = 61$), followed by insufficient SR ($n = 39$), and high TA ($n = 38$), whereas sufficient SR ($n = 45$) dominated in the 'In-vigour' profile, followed by insufficient SR ($n = 38$), and high TA ($n = 24$). However, low TA in combination with sufficient SR was reported by 27 pupils and, in this context, 13 pupils recorded high WMC in combination with sufficient SR. See Figure 1 and Table 5.

Relationship between the profiles of WM, TA and SR, and Maths scores

In the sample 11.5% of the pupils were observed with low Maths scores, and 8.3% with high Maths scores. Within the low Maths scores, 47 pupils (65%) were identified with an 'At-risk' profile, while 3 pupils had an 'In-vigour' profile. Among the high Math scores, 25 pupils (47%) were identified with an 'In-vigour' profile, while 6 pupils had an 'At-risk' profile. Of the 190 pupils observed with an 'At-risk' profile, 47 pupils (25%) were in the group of low Maths scores, whereas only 6 pupils (3%) were in the group of high Maths scores. Further, 10% of the 'None' profile, and 9% of the 'Mixed' profile scored 1 sd. below the mean scores for maths (Figure 1, Table 5).

The independent samples chi-square statistic showed there was a significant association between the mathematical achievement and profile of a pupil: $\chi^2(6, N = 624) = 62.610, p < .0001$. The association was of moderate strength: $\phi = .317$, and the share of variance accounted for in the association between profile and Maths scores was 10%. Based on a relative risk calculation (24.7% vs. 75.3%, and 1.9% vs. 98.1%), the risk of a pupil receiving low Maths scores if identified with an 'At-risk' profile is 13 times more likely than for a pupil identified with an 'In-vigour' profile.

Discussion and conclusion

The present study provides an example of the need to broaden the standards of an 'at-risk' pupil to also include emotional-cognitive difficulties. The emotional-cognitive circuit interference is an empirical phenomenon with a wide range of potential theoretical explanations where impaired cognitive processing is the most prominent. Hence, it is well established that WM correlates with academic achievement, and that WM processing is crucial in higher order cognition, e.g. mathematical ability (Ullman et al. 2014). But WM is vulnerable to interruptive factors such as TA which affect WM operations (Owens et al. 2014). However, a pupil's ability to self-regulate possibly blocks this intrusion (Hofmann et al. 2012). In addition, recent reports

Table 5. Frequencies and clusters of High (H)- and Low (L) wmc, ta, and sr, in total and allocated between High- and Low math, respectively, designated as 'At-risk'-, 'Mixed'-, 'In-vigour'-, and 'None'-status groups. Sets of combinations of +1 sd. above mean score (H) and -1 sd. under mean score (L), respectively, encompassing TA, SR, and WMC, in +/− 1 sd. above/under mean math scores, respectively. Rows; status-group including: three variables – dark grey coloured; two variables – grey coloured; one variable – white coloured

At-risk	*n*	High math	Low math
LwmcHtaLsr	9		3
LwmcLsr	18	1	6
HtaLsr	14	1	3
LwmcHta	11		6
Lwmc	61	1	16
Lsr	39		8
Hta	38	3	5
n	*190*	*6*	*47*
Mixed			
HwmcHtaLsr	3		
LwmcHtaHsr	1		
LwmcLtaLsr	1		1
LwmcLta	7	1	2
HwmcHta	5		
HwmcLsr	5	1	
LwmcHsr	3		
HtaHsr	2		
LtaLsr	2		
LwmcLtaHsr	4		
HwmcLtaLsr	1	1	
n	*34*	*3*	*3*
In-vigour			
Hsr	45	7	1
Hwmc	38	7	1
Lta	24	2	
LtaHsr	27	3	1
HwmcHsr	13	2	
HwmcLta	7	1	
HwmcLtaHsr	7	3	
n	*161*	*25*	*3*
None			
n	*239*	*19*	*19*
TOTAL	624	53	72

have also drawn attention to the importance of WM, TA and SR by highlighting concerns about childhood well-being and development (Murphy and Fonagy, 2013).

The purpose of this study was to investigate differences in psycho-educational profiles (comprising WM, TA and SR) associated with mathematical achievements,

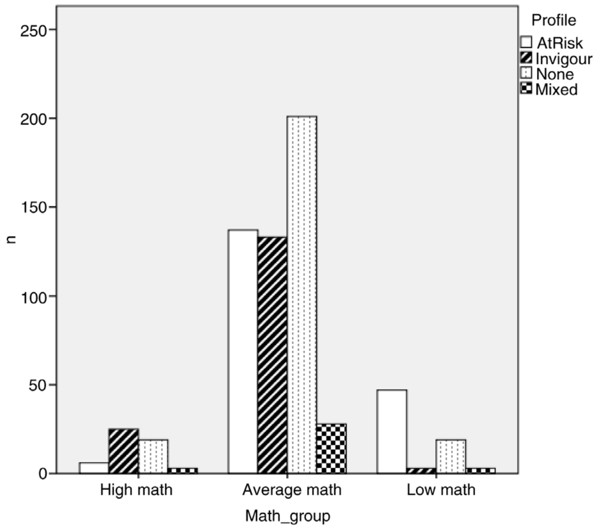

Figure 1. Columns: frequencies for designated sets of 'At-risk'-, 'In-vigour'-, 'None'-, and 'Mixed' status; in High Maths scores-, Average Maths scores-, and Low Maths scores-groups, respectively (x-axis).

and whether psycho-educational profiles can distinguish subgroups of pupils that meet discrepancy definitions with regard to mathematical achievements. Our discrepancy-based approach was therefore based on the notion that a child who is deficient in mathematical achievements may or may not differ in their psycho-educational profiles.

Not surprisingly, various combinations of WM, TA and SR at different levels were found, yet profiles including one single variable were most common. It was also no surprise that the recognised 'positive' and 'negative' levels of WMC, TA and SR operated together in combinations, for example low WMC and high SR in the same profile. The number of pupils with such so-called Mixed profiles were, however, the least common. In total, profiles comprising 25 different combinations were observed.

We also expected that among high and low Maths scores, respectively, both 'At-risk' and 'In-vigour' profiles would be observed. In this line of reasoning, there was a significant statistical relationship between profile and mathematical achievement. Pupils endowed with an 'At-risk' profile were 13 times as likely as pupils identified with an 'In-vigour' profile to get low Maths scores.

Although the associations in the present study between Maths scores and WMC ($r = .40$), SR ($r = .29$) and TA ($r = -.26$), respectively, were significant ($p < .001$), a mere 25 pupils of the 161 pupils with an 'In-vigour' profile scored highly in Maths. An additional three pupils endowed with an 'In-vigour' profile scored lowly in Maths. Further, of the 190 pupils identified with an 'At-risk' profile 47 pupils scored lowly in Maths. In the present study, 19 pupils also scored lowly in Maths and 19 pupils scored highly in Maths but did not show any 'At-risk' or 'In-vigour' profile, respectively.

Even if we need to remain aware of the different individual variations of the underlying mechanisms, we argue that it is fair to say that education has let down many of those pupils who have vigour premises. Due to inadequate support or inaccurate teaching methods, some pupils in the present sample have conceivably not developed as far as possible or managed to perform to their best (see Bejerot and Nordin, 2014; Fernell, Kadesjö, Nylander and Gillberg, 2014). Others may have been unmotivated and thus performed below their capacity in the maths tests (see Eklöf and Nyroos, 2013). Other studies also state that academic self-concept, perceived learning difficulties, educational aspirations and socioeconomic status are linked to educational outcomes (e.g., Korhonen, Linnanmäki and Aunio, 2014; Tuominen-Soini et al. 2012), which could have been the case for some of those pupils.

The same can be said for sets of 'At-risk' profile. A low WMC, high TA, or low SR does not automatically mean school failure. Although labelled as 'At-risk', 75% of the group did not score lowly in maths, and six pupils even scored highly in maths. We can only speculate on what other factors can explain those pupils' non-low Maths scores, although it seems reasonable that the aforementioned aspects hindering mathematical achievement operate in the opposite way (cf. Gustafsson et al. 2010).

A great individual implication is that 143 pupils were identified with an 'At-risk' profile. Many pupils who felt they are within the range of 'normal' in academic achievement may possibly encounter difficulties, now or in the future, due to emotional-cognitive interference. Hence a pupil who is performing at an acceptable attainment level but has an 'At-risk' profile may be at risk for future attainment problems, such as mental health problems, when the levels of academic demands increase (see Tuominen-Soini et al. 2012). In addition, although the level of severity was 'subclinical' (noting that the present assessment battery is not intended for clinical use) the impairments may, in some cases, result in substantial limitations and long-term disadvantages. Yet, because those pupils scored averagely in the maths tests they are likely not qualified for special educational provision or Pupil Health Care, and we thus argue that their needs are being overlooked.

Nonetheless, what has been suggested in the literature is that adopting different interventions or teaching strategies – regardless of whether one is targeting WM, TA or SR – have the great advantage of positively affecting *all* pupils, and not just those pupils 'appearing' to be in the need of special provision (Gathercole and Alloway, 2008; Weems et al. 2014; von der Embse and Hasson, 2012). Considering the 'cascade effect' – interventions seem to have a spill-over effect, for example when behaviour problems are reduced internalised problems are also likely to decline (see Masten and Cicchetti, 2010) – the scope for interventions seems promising.

To summarise the present findings, it is quite clear that no particular variable or combination of variables stands alone as a central component of *all* pupils' mathematical achievement. Still, it is evident that low WMC and/or high TA and/or low SR likely are what characterises a fairly large proportion (65%) of pupils scoring 1 sd.

below the mean Maths score, and high WMC and/or low TA and/or high SR are involved in a number of pupils (47%) scoring 1 sd. above the mean Maths score.

The current study was primarily limited by its indirect line of reasoning as our conclusions derive from objective measures and standardised scales. Moreover, the decision to not use, for example, regression analyses was made because these types of analyses only capture linear relations between the predictors (WM, TA and SR) and the dependent measure (maths achievement). With a person-centred approach we were able to find non-linear relations by identifying different profiles and examining their relations to mathematics. However, an even more subjective phenomenon falls beyond of the scope of this study. If supplemented by interviews or observations, more complete information about the reasons could have been provided. Hence, a recommendation for future studies is to take this issue on and consider each approach on its merits.

Even though the present sample is non-randomised, owing to there being no exclusion criteria, and few participants non-systematically declined participation, it is arguably representative of a typical school sample of Swedish grade 3 pupils. The findings of this study hold several implications when applied to a special educational setting. By recognising the potential scope for raising the academic attainment of pupils by addressing emotional-cognitive factors, it is postulated that the adoption of widespread school-based interventions should be embraced by teachers of all teaching groups, directed by the Pupil Health Care Act, and instituted within special education (see Socialstyrelsen, Skolverket, 2014). However, no recommendations about the utility and efficacy of developmentally-modified cognitive-based intervention programmes for a Swedish school setting can be made until a full trial is conducted in the future. Before that occurs, the literature has suggested interventions aimed at helping pupils with internalised and externalised difficulties, which are believed to be involved in transient processing defects or difficulties in performing academic skills, and mainly based on cognitive-behavioural theories (see Akinsola and Nwajei, 2013; Esbjørn et al. 2013; von der Embse and Hasson, 2012; Vytal et al. 2013; Weems et al. 2014).

Other suggestions for appropriate preventative measures to take into account are, for example, the need to consider the messages and signals educators communicate through their expressions, traditions and culture, and in their relationships with pupils. Pupils prone to emotional difficulties easily discern and/or misinterpret a meaning. Fostering a learning environment free of emotional enforcement and tolerant of mistakes would improve the situation. Presenting failure as a natural mechanism that provides an opportunity to learn prevents avoidance of the fear of failure (a predictor of anxiety). In addition, mental health can be improved by properly preparing for exams and not generating expectations of success, thus focusing on the study subject (but not surface learning) rather than on the outcome of the exam (see Putwain and Daly, 2013; Roslander, 2013; von der Embse and Hasson, 2012).

Sweden has an education system that is one of the most decentralised among the OECD countries (Rönnberg, 2011) and includes many elements such as individualisation, marketing and entrepreneurship, with each not necessarily suiting groups of pupils with different difficulties and needs (Cederblad, 2013; Hjern, Alfven and Östbeg, 2008; McDonald Connora et al. 2010). In keeping with this, the OECD (2014) recently concluded that the Swedish education system faces vast problems with inequity and that the greatest burden of this (in)equitable education system falls on those pupils who need special educational provision. Therefore, to provide access for *all* pupils to educational entitlements the field of special education needs to move past the discourse associated with the preamble paragraph in Swedish education of educational equity cross-curricula (i.e., an equitable opportunity to learn in school), and prepare teachers with knowledge of emotional-cognitive factors which are those common to impaired educational outcomes and several childhood mental health problems (see Mulcahy et al. 2014; Owens et al. 2012). The present paper thus challenges the prevailing understanding of who to label 'at-risk', and thus testifies to the incongruities of educational equity contrasted with individual differences.

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