Sense and nonsense of metacognition as 'second order skills' in relation to specific learning disorders

Annemie Desoete

Abstract

After an introduction on 'second order skills '(metacognition, Executive Functions or EF, self-regulation and Effortfull Control or EC) and on specific learning disorders (dyslexia/dyscalculia), we focus on the 'nexus' between both constructs in five studies. In study 1 we compared prediction and evaluation skills in children with and without learning disabilities. In addition we revealed that children with procedural dyscalculia had poor prediction and evaluation skills (study 2) and that persons with dyslexia and dyscalculia had below average working memory and planning skills (cold EF – study 3) with children with dyslexia also having problems with inhibition (hot EF – study 4). When analyzing metacognition in adolescents study 5 demonstrated that poor spellers are also were poor in detecting spelling mistakes. Moreover study 6 demonstrated that high functioning adolescents with dyslexia show a lot of similarities on hot and cold EF with peers without dyslexia. Finally study 7 demonstrated that metacognition can be trained in the case of a 'production deficiency' with an informed, prolonged and embedded training and that metacognition can be considered from a Universal Design for Leaning (UDL) perspective as 'tool' taking into account the different Process Communication Model (PCM) personality types (Kahler, 2008; Pauley & Pauley, 2012).

Key Words: Metacognition, Executive functions, Efforfull control, Learning Disabilities

Introduction

Proficient reading, spelling and math skills are of central importance to modern society in all countries and become increasingly essential in many job profiles. In some children learning to read, spell or calculate is more difficult than in their peers (Desoete, 2014;2015). In addition, children begin formal education with a very positive view of learning and with 'good feelings about their own abilities'. However both interest and motivation decline as children grow older (Moore, Rudig, & Ashcraft, 2015) and especially in girls the positive affect and 'good feelings' fade away (OECD, 2015). Given the high cost associated with poorly developed learning skills, it is essential to tackle this underperformance by gaining insight into the processes of decline leading to a suboptimal learning development.

This contribution is attributed to the role of metacognition in the pursuit to explain suboptimal learning. After an introduction on suboptimal learning and specific learning disorders (dyslexia/dyscalculia), definitions of metacognition, Executive

Annemie Desoete, Universiteit Ghent, Department of Experimental Clinical and Health Psychology, Annemie.Desoete@ugent.be

Functions (EF), self-regulation and Effortfull Control (EC) as models for 'second order' skills will be given.

Suboptimal learning

The DSM 5 differentiates specific Mathematical Disorders from specific Reading Disorders, all having impairment in mathematics or reading and written expression.
Specific Mathematical Disorders (MD) or dyscalculia can be described as impairments where math abilities remain persistently at a level that is significantly below expected given the age and where this suboptimal learning can not be explained by extraneous factors, such as sensory deficits and have to be persistent. In order to be sure of the persistence of MD, it is important to consider consistency in performance over time (Fletcher et al., 2005; Mazzocco & Myers, 2003). Most researchers currently report a prevalence of MD between 3-14% of children (Barbaresi, Katusic, Colligan, Weaver, & Jacobsen, 2005; Desoete, 2014;2015; Geary, 2011a&b; Rubinsten & Henik, 2009; Shalev, Manor, & Gross-Tsur, 2005; Tosto, Haworth, & Kovas, 2015).

Specific Reading disorders (RD) or dyslexia can be defined as impairments where reading and/or written expression (spelling abilities) remain persistently and significantly below expected given the age and effective teaching (Pennington et al., 2012; Ziegler et al., 2008). The prevalence of RD is approximately between 5 to 12% of children (Schumacher, Hoffmann, Schmal, Schulte-Korne, & Nothen, 2007). However, since language and orthography play an important role in reading, prevalence of RD may differ across countries (Callens, Tops, & Brysbaert, 2012). Clear differences are marked between regular and more irregular orthographies and it assumed that different problems are manifested in RD in languages that embed regular grapheme-phoneme correspondence than in languages with a less transparent orthography and grapheme-phoneme mapping (Bergmann & Wimmer, 2008; Callens et al., 2011).

Second order skills

Several constructs are used to focus on 'second order skills'. **Metacognition** is a concept introduced by Flavell in 1976 (meta-memory). He described metacognition as 'one's knowledge concerning one's own cognitive processes and products and anything related to them…' Once metacognition gained popularity, most authors agreed to differentiate a knowledge and skills component. Sometimes they also describe a metacognitive experience component.

Metacognitive knowledge has been described as the knowledge, awareness, and deeper understanding of one's own cognitive processes and products (Flavell, 1976). According to Efklides (2008, p. 208) metacognitive knowledge is «declarative knowledge stored in the memory and comprises models of cognitive processes. It also encompasses information about people (including one's self), as well as information about tasks, strategies, and goals. Metacognitive task-knowledge involves task categories and their features, relations between tasks, as well as the ways they are

processed. Metacognitive strategy-knowledge involves knowledge of multiple strategies as well as the conditions for their use (e.g., when, why and how a strategy should be used). Finally, metacognitive goal-knowledge involves knowledge of what sort of goals people pursue when confronted with specific tasks or situations.» Another related conceptualization of metacognitive knowledge distinguishes declarative, procedural and conditional (or strategic) metacognitive knowledge (Brown, 1987; Schraw, 1997; 1998). Declarative knowledge is concerned with knowledge of the strengths and weaknesses of one's own processing ability as a learner and knowledge about cognitive strategies (Brown, 1987; Georghiades, 2007). Procedural knowledge involves knowledge of how to successfully employ particular cognitive strategies in order to achieve learning objectives (Brown, 1987; Perfect & Schwartz, 2002; Pintrich, 2002; Schraw, 1998). Conditional knowledge refers to knowledge of the appropriateness of particular cognitive strategies when taking into account external learning conditions, including awareness of the underlying reasons for cognitive strategies' effectiveness (Brown, 1987; Pintrich, 2002; Schraw et al., 2006; Zimmerman & Schunk, 2011). Conditional knowledge is critical to effective use of strategies (Harris, Graham, Brindle, & Sandmel, 2009). Novices have been found to possess poorer metacognitive skills than experts (Kruger & Dunning, 1999). Students doing poorly on tests predicted less accurately which questions they would get right than students doing well (Kruger, 2002; Kruger & Dunning, 1999; Sinkavich, 1995).

Metacognitive skills refer to «the deliberate use of strategies (procedural knowledge) in order to control cognition» (Efklides, 2008, p. 280). According to Brown (1980), executive control (or "metacognitive skills") can be seen as the voluntary control people have over their own cognitive processes. There are four basic metacognitive skills identified in the literature: prediction, planning, monitoring, and evaluation (Desoete, 2007a, 2007b; Desoete & Roeyers, 2002; Desoete & Veenman, 2006; Lucangeli & Cornoldi, 1997). In spelling, test prediction refers to student activities aimed at differentiating which words will require attention and possible further action (such as words with [ei] or [ij]). Planning involves analysing the demands of the spelling exercises, retrieving relevant domain-specific knowledge and skills (e.g., when to use capitals), and sequencing of problem-solving strategies. Monitoring is related to questions such as "am I following my plan?", "should I write a word on another piece of paper to check if the spelling on the test sheet is correct?" and so on. In evaluation there is self-judging of the answer and of the process of getting to this answer.

Metacognitive experiences (ME) have been described as «what the person is aware of and what she or he feels when coming across a task and processing the information related to it» (Efklides, 2008, p. 279). ME take the form of metacognitive feelings, metacognitive judgments/estimates, and online task-specific knowledge. Metacognitive feelings are non-analytic representations of knowing states with an affective and cognitive character. The affective character of metacognitive experiences can be explained by two feedback loops. The first one is related to the outcome of cognitive processing and detects the discrepancy from the goal set. Error detection (as discrepancy from the goal) and feeling of difficulty (as lack of processing fluency) are

associated with negative affect (Efklides, 2006). Metacognitive judgments/estimates include analytic and non-analytic processes, such as judgment of learning, estimate of effort expenditure, estimate of time needed or spent, but also estimate of solution correctness. When people are asked to make a judgment about their confidence there are two sources of information on which they rely, according to Efklides (2008), namely their estimate of solution/response correctness (as discrepancy of the response to the goals) and their feeling of difficulty (as cue that the response might not be correct). Metacognitive experiences, in essence, make the person aware of his or her cognition and trigger control processes that serve the pursued goal of the self-regulation process (Efklides, 2008; Koriat, 2007; Schraw & Dennisson, 1994). However, the person can feel highly confident, even if the outcome of cognitive processing is not correct, just because the solution was produced fluently, thus endangering appropriate control decisions. This is particularly true for persons who are not aware of their ignorance (Efklides, 2008; Kruger & Dunning, 1999).

Nowadays, a lot of **diagnostic tools** are designed to assess metacognition (Desoete, 2008; Desoete & Roeyers, 2006). The mainstream of those tools is self-report questionnaires used to assess metacognitive knowledge and self-ratings to measure metacognitive experiences (Efklides, 2008). The prospective measurement of metacognitive knowledge has to do with metacognitive judgments elicited before problem solving. Retrospective measures of metacognitive knowledge involve self-reports of strategies or metacognitive experiences after problem solving. Several studies underlined the importance of questionnaires and ratings (Busato, Prins, Hamakers, & Visser, 1998). However, Veenman, Van Hout-Wolters and Afflerbach (2006) pointed out the limited explained variance towards learning outcomes by self-report questionnaires. Moreover, only moderate correlations were demonstrated between prospective and retrospective measurements of metacognitive knowledge (Veenman et al., 2006). Hence, in addition to the self-report measures, think-aloud protocols or systematic observation of behaviour can take place to measure metacognitive skills (Veenman & Elshout, 1999). These analyses were found to be very accurate, but time-consuming, techniques to assess metacognitive skills (Pressley, 2000). Recently, multi-method techniques are also being used. Often these techniques combine measurements of metacognitive experiences and/or knowledge. For example, students are asked, before and after the processing of a task, to assess the difficulty they experience, the correctness of the solution (conceived or produced), the effort required, and to make subjective estimations about the use of problem-solving strategies. Finally, in calibration studies a comparison is made of whether the prediction before the tasks ("calibration" or comprehension paradigm) or the evaluation after a task ("performance calibration" or postdiction paradigm) corresponds with the actual performance on the task. Calibration studies are therefore most closely related to the assessment of metacognitive experiences and refer to the reliability of metacognitive experiences (Vanderswalmen, Vrijders, & Desoete, 2010).

The use of the concept **Executive functions** (EF) as second order skills is another attempt to explain individual differences in learning from a neuroscience approach (Barkley, 2001; Desoete & De Weerdt, 2013). EF has here been described as

control mechanisms in the frontal cortex that coordinate, regulate and control cognitive processes during the operation of cognitive tasks (Miyake et al., 2000).

There are several EF-models (e.g., Baddeley, 1986; 2000, Barkely, 2001; Miyake et al., 2000, Pennington, 2006). In the Baddeley working memory model, the central executive is an attentional control system, which executes the processing aspects of a task (Baddely, 1996; 2002; Baddely, Allen, & Hitch, 2010). The central executive strongly interacts with one multi-dimensional and two domain-specific storage systems. The phonological loop is responsible for the storage and maintenance of verbal information; the visuospatial sketchpad has similar responsibilities for visual and spatial information (Baddeley, 1986). Forward recall tasks have been used as measures of the phonological loop and the visuospatial sketchpad, while backward recall and dual span tasks are used as measures of the central executive.

However EF cannot be reduced to working memory. Inhibition is also a crucial executive function (Miyake et al., 2000). Several authors have added that inhibition is not a unitary construct, but rather a family of functions (Friedman & Miyake, 2004; Nigg, 2000). In Nigg's (2000) taxonomy, executive or effortful inhibition can be differentiated in interference control, behavioral, oculomotor and cognitive inhibition. Interference control refers to the ability to maintain response performance and suppress competing, distracting, or interfering stimuli that evoke a competing motor response (Nigg, 2000). The Stroop task is one of the most widely cited measures of interference control in literature (Nigg, 2000). In addition, behavioral inhibition can be defined as the capacity to suppress a prepotent or dominant response (Nigg, 2000). Behavioral inhibition can be targeted by a Go/no-go task (Friedman & Miyake, 2004; Purvis & Tannock, 2000). Myake et al. (2000) added shifting and updating to inhibtion as important EF. Pennington (2006) added planning, cognitive flexibility and verbal fluency to inhibition and (visual) working memory as important EF. Moreover, Ardila (2013) stressed the difference between 'hot' and 'cold' EF. Hot EF referred to the emotion regulation or the inhibition. Cold EF referred to metacognition. Finally, Waber (2014) differentiated content dependent and content independent EF, with a different neuroanatomical system as neural correlate. The decontextualized EF was located in the anterior parahippocampale gyrus. The contextualized EF was located in the posterior parahippocampale gyrus. Waber reported a correlation between the cortical thickness (not volume) of the hippocampal posterior gyrus and the BRIEF. There were no significant correlations between cortical structures and decontextualized EF measures.

More recently, **self-regulation** became dominant as a concept referring to a planned and cyclical way of regulating thoughts, feelings and actions to meet personal goals (Boekaerts & Corno, 2005; Boekaerts , Pintrich, & Zeidner, 2000; Dignath-van Ewijk, 2011; Dignath, Buettner, & Langfeldt, 2008; Zimmerman & Schunk, 2001). Within this framework self-regulated learners are characterized by three important characteristics: they are metacognitive active participants in their learning process, motivated to learn and strategic (Winne, 2011; Zimmerman & Schunk, 2011). This self-regulation model includes a metacognitive, a motivational and a cognitive component.

Studies on **Effortful Control** (EC) looked longtime in the relative shadow at the self-regulation component of temperament (Rothbart & Bates, 1998). Rothbart (1989; 2004) defined EC as the ability to inhibit a dominant response to perform a subdominant response. EC involves inhibitory/activation control and attentional control. Since the renewed interest in the emotions and emotional development, EC-studies related to social, emotional and cognitive development allowed us to consider typical learning and to different forms of pathology. The conceptual overlap of EC and other constructs such as executive functions (inhibition), inference control, intentional motor inhibition is obvious.

The measurement of EC takes place with self-reports (such as the Effortful Control Scale ECS or the Attentional Control Scale ACS etc.), parent-reports (such as the Early Adolescence Temperament Questionnaire –Revised, EATQ-R) and neuropsychological measures (go/no go task, stroop task, stop task, …).

Moreover Kahler (1971) described in his Process Communication Management (PCM) model six **personality** 'bases' in a pursuit to understand differences in motivation in children. 'Empathic' children (30% of the population, 1:4 boys-girls) are attentive for the others and sensitive, motivated by a well-willing management style, work in groups with a lot of sensory stimulation and getting recognized and acknowledged as a person. 'Thinkers' (25% of the population, 4:1 boys-girls) are children that are responsible, logical and organized, performing best in a democratic management style where they can work alone with recognition of her/his work and time structure. 'Persisters' (10% of the population, 4:1 boys-girls) are devoted, good observers and conscientious children, motivated by a democratic management style where they can work alone with recognition of work done and respect for opinions. Children with a 'dreamer' personality (10% of the population, 2:3 boys-girls) are imaginative, reflective and calm, needing an autocratic management style respecting their need of solitude but also inviting them to act. Children with a 'rebel' personality (20% of the population, 2:3 boys-girls) are spontaneous, creative and playful, enjoying the here and now and motivated by playful 'contact' of teachers with a 'laissez faire' management style inviting them to work in a group to group environment. Children with a 'promoter' personality (5% of the population, 3:2 boys-girls) are convincing, adaptive and capable to realize things, but needing strong sensations and actions and an autocratic management style to be motivated. PCM might help to broaden the picture and the psychological needs to be motivated of boys and girls (Pauley & Pauley, 2002). The PPI (Personality Pattern Inventory; Kahler, 2004; 2008) is a questionnaire related to the PCM model.

Research Questions

Although a certain consensus has been reached that higher order skills have an important effect on learning achievement, several questions about the interchangeability of the constructs of metacognition, EF, self-regulation, EC and personality remain unresolved and the 'nexus' with individual differences in learning yields inconsistent results

To enhance our understanding of these higher order skills, the metacognitive profile of children and adolescents and the possibility of training metacognition were studied. In what follows different studies will be described on metacognition/EF in children (part 1) and adolescents (part 2) with suboptimal learning skills. Moreover it is studied if metacognition can be enhanced (part 3).

Procedure

In a first study children with specific mathematical learning disabilities in grade 3 (MLD) (n=29 boys and 33 girls) were compared with peers with specific reading disabilities (RLD) (n=40 boys and 32 girls), children with combined reading and mathematical learning disabilities (MRD) (n=40 boys and 32 girls), age-matched peers (NoD3) (n=70 boys, 60 girls) and younger children (NoD2) (n=52 boys and 68 girls) matched at mathematical problem-solving level. For more information, we refer to Desoete and Roeyers (2002).

In the second study 58 children (30 boys, 28 girls) with a mathematical learning disability due to insufficient procedural skills (PRD), 88 children (44 boys, 44 girls) with a semantic memory disability (SMD) and 45 children (25 boys, 20 girls) with a combined disability in both aspects of mathematical problem-solving (CoD) participated.

In study 1 and 2 children completed the Evaluation and Predication Assessment computerized test (EPA2000) (De Clercq, Desoete & Roeyers, 2000) In the EPA2000 (De Clercq et al., 2000) cognition and metacognition is assessed. Before solving the different mathematical tasks, children first have to ‘predict’ their performance . After doing the exercise, children ‘evaluate’ on the same 4-point rating scale. Metacognitive predictions (Pr) or evaluations (Ev) are awarded two points whenever they correspond with the child’s actual performance on the task. Predicting and evaluating rating ‘sure to be correct’ or ‘sure not to be correct’ receive one point whenever they correspond. Other answers receive no points, as they are considered to represent a lack of prediction / evaluation. For the cognitive mathematical problem-solving, children obtain l point for every correct answer.

Moreover in study 3 working memory and planning (cold EF) were studied in 112 children with and without learning disabilities. (Backward) digit -, word list -, listening - and block recall were used to assess working memory. In addition all children were tested with the spatial span and the backward word list recall and backward block recall were used.

In study 4 inhibition (hot EF) was studied in 161 children with and without learning disabilities with a Go/no-go paradigm with three different modalities.

In study 5 a total of 2,095 first year bachelor students participated (594 boys and 1,501 girls). At the time of testing their mean age was 18.82 years (SD = 1.80). Participants completed two questionnaires created for the present study, namely a prospective and a retrospective metacognition questionnaire. The Prospective Metacognition Questionnaire (PMQ) assessed student’s metacognitive knowledge (MK) of the self as speller and student’s use of MS in spelling, namely checking of spelling.

The MK of the self as speller was measured as follows. Participants were required to rate their own spelling skills, as compared to peers, on a 7-point scale ranging from 1 (very bad) to 7 (very good). The use of MS was assessed with one item by asking participants how often they read through their own texts, letters, and e-mails to check for any spelling errors. Responses were on a 5-point rating scale, varying from 1 (never) to 5 (always). The Retrospective Metacognition Questionnaire (RMQ) assessed metacognitive experiences, namely feeling of confidence (FOC; metacognitive feeling) and estimate of the number of spelling errors (EOSE; metacognitive judgment). Also, a score showing the correspondence between the ratings of FOC and actual performance was calculated. Participants took the Dictation test during the first semester of the academic year. The PMQ was completed before the Dictation test. The RMQ was completed after the Dictation test. All sessions were carried out collectively in classrooms, after assuring good testing conditions.

In a sixth study 200 first-year undergraduate students of higher education with and without dyslexia participated in the study, both students of professional bachelors and students of university bachelors. No significant differences were found between students on intelligence ($F (1, 198) = 0.84$; $p = .36$). All students rated their study motivation and study skills by means of a validated Dutch version of the Learning and Study Strategies Inventory (LASSI; Weinstein & Palmer, 2002). Each scale contains 8 items, except the 5-item scale “selecting main ideas”. In this test, three components of metacognitive knowledge or self-regulated learning can be distinguished: determination (1), knowledge of metacognitive regulation strategies (2), and knowledge of cognitive processing strategies (3). Feeling of confidence (FOC) as a measure for metacognitive experiences was assessed with the two subtests of the GL&SCHR. Participants had to evaluate their own performance on a word spelling dictation (production task) and a proof reading task (detection of spelling mistakes in the use of rules to write words and sentences). They always had to rate how certain they felt about the answer (certain, almost certain, uncertain) as a measure of FOC. The FOC score is thus influenced by the degree of certainty of the writer and is the sum of the following scores per item. Finally monitoring or task-switching (a metacognitive skill) was assessed with a test where 960 digits from 0 to 9 are presented in 16 columns. Students had three minutes to underline as many fours and to blot out as many threes and sevens as possible. In addition all participants completed the BRIEF and PREF (self-report questionnaires).

Finally the effectiveness of a short metacognitive intervention combined with algorithmic cognitive instruction was studied in 237 children in grade 3 (study 7). Children were randomly assigned to a 5-session metacognitive strategy instruction, an algorithmic direct cognitive instruction, a motivational program, a quantitative-relational condition, or a spelling condition.

Results

Study 1 revealed that children with specific or combined MD had prediction and evaluation skills comparable to those of children one year younger. However, on analyzing this performance further, significant differences were found compared to

those children without learning disabilities, matched at the level of mathematical problem solving. Children with MD had more problems to predict and evaluate their performances on easy tasks than younger children.

Study 2 revealed that not all, but about a third of children with MD had inaccurate metacognitive skills. This was the case for about two third of the children with a combined disability, half of the children with a procedural disability and only for about 5% of the children with a semantic memory disability.

Study 3 revealed the importance of tasks measuring working memory (cold EF). Evidence was found for domain-general working memory problems in children with learning disabilities.

Study 4 revealed the importance of inhibition (hot EF) in children with RD and response speed deficits in children with RD and MD. The latter were found to be domain-general in children with RD and alphanumeric or symbolic in children with MD (De Weerdt, Roeyers, & Desoete, 2013a&b).

In study 5 adolescents in the bottom quartile rated themselves as less competent, checked their texts less frequent, had a significantly lower FOC and estimated that they made more errors compared to peers in the other quartiles. Ratings of MK of the self as speller and use of MS predicted about one sixth of the variance of spelling performance. Also FOC ratings predicted about one fourth of the same variance. Finally, EOSE predicted about one sixth of the same variance (Vanderswalmen, Vrijders, & Desoete, 2010).

In study 6 there was a difference in metacognitive experience (ME) between adolescents with and without dyslexia, more precisely in the feeling of confidence (FOC) regarding their spelling abilities. Students with dyslexia seemed to be less certain about the correct spelling of self-written words in comparison to peers with no spelling impairment. This was particularly true for correctly spelled words. There was indeed a striking difference in the FOC score of correct and incorrect answers. When words were misspelled, the FOC of the dyslexic students did not differ significantly from that of their peer students. This pattern of FOC was also found in a proof reading task where both student groups were asked to recognise and correct sentences and words containing (rule-related) spellings. Again students with dyslexia doubted more about correctly written words and sentences than students without dyslexia, but they did not differ from their peers in the feeling of confidence about incorrect answers. In addition, the study revealed that students with dyslexia reported more difficulties with dissociating main issues and details. Besides, they claimed to dispose of less efficient test strategies to test if they constrained the curriculum content (Tops, Callens, Desoete, Stevens, & Brysbaert, 2014). In addition high functioning students with dyslexia had different metacognitive experiences and skills, not comparable to the experience and skills of peers without learning disabilities on the BRIEF and PREF.

Finally, in study 7 the effectiveness of a short metacognitive intervention combined with algorithmic cognitive instruction was demonstrated on 237 subjects randomly assigned to a 5-session metacognitive strategy instruction, an algorithmic direct cognitive instruction, a motivational program, a quantitative-relational condition, or a spelling condition. Children in the metacognitive program achieved significant gains in trained metacognitive skills compared with the four other conditions, with a follow-up effect on domain-specific mathematics problem-solving knowledge. Thus,

metacognition was found to be modifiable with value added to mathematical problem solving (e.g., Desoete, 2007a&b; 2009a&b&c).

Discussion

Study 1 revealed that suboptimal learning in **children** is often accompanied with problems to predict task difficulty. In addition the problems to predict performances is even obvious on easy tasks. However, study 2 demonstrated that metacognition is not missing in all children with LD. Children with semantic memory dyscalculia did not seem to have metacognitive problems whereas children with procedural dyscalculia or combined disabilities had less accurate metacognitive skills than peers without learning problems. In addition in study 3 suboptimal cold EF (working memory) was present in children with RD and / or MD. Moreover study 4 revealed problems with hot EF (inhibition) of a domain-general nature in children with RD and alphanumeric or symbolic in children with MD .

Study 5 demonstrated in **adolescents** that had suboptimal spelling skills rated themselves as less competent, checked their texts less frequent, had a significantly lower FOC and estimated that they made more errors compared to peers in the other quartiles. We can conclude that metacognitive knowledge and skills can give valuable information on the spelling skills of college students. Poor spellers seemed also to be poor in detecting spelling mistakes (Vanderswalmen et al., 2010). In addition study 6 revealed that students with dyslexia doubted more about the correct spelling of word when the word was correctly spelled. Nevertheless, students with dyslexia seemed to be as capable as non-spelling-impaired peers to recognize wrongly spelled words (Tops et al., 2014). In addition adolescents dyslexia had below average inhibition scores and skills to deal with testing (hot EF) and they reported more problems with working memory and planning (cold EF).

In addition a short metacognitive program (in study 7) was able to enhance domain-specific mathematics problem-solving knowledge. Thus, with explict training, metacognition was found to be modifiable with value added to mathematical problem solving (e.g., Desoete, 2007a; 2009c). This is in line with Hartman and Sternberg (1993) summarizing four main approaches: promoting general awareness by modelling by teachers, improving metacognitive knowledge (knowledge of cognition), improving metacognitive skills (regulation of cognition) and fostering on learning environments. In addition this is line with Veenman (2013) who pointed to the fact that metacognition can be trained in a production deficiency with an informed, prolonged and embedded training.

Conclusion

Metacognition, EF, self regulation and EC are overlapping models developed to understand and predict proficient or typical and suboptimal or atypical learning. In the past there were attempts to get a consensus on the definition and assessment of these constructs, since how you test is what you get (Desoete, 2008). However, up till now such a consensus seems still far away. Therefore, it might be better not to try to convince researchers to use the same concepts, but to agree to define their concepts used

in studies as well as measurements of these concepts very clearly. This way researchers can combine their insights and try to understand differences and similarities and judge the interchangeability of study results.

In addition, although teachers still pay little attention to the explicit teaching of second order skills, studies seem to point to the fact that these second order skills are especially important for some children and adolescents. Several studies demonstrated that such second order skills (often described as metacognitive skills but from another perspective described as self-regulated learning or 'cold' executive functions) need to be taught explicitly in order to develop and to enhance proficient learnings. We suggest that such a training promoting metacognitive awareness (Schraw, 1998; Schraw & Nietfeld, 1998) should be integrated in a Universal Design for Leaning (UDL) approach. A UDL framework aims at creating learning environments and adopting teaching materials and practices that allow for participation by all children, regardless of individual learning differences (Hanna, 2005). As such, UDL principles lend themselves to implement inclusionary practices in general educational settings, because it consists of flexible approaches that can be customized and adjusted for individual needs (Hitchcock, Meyer, Rose, & Jackson, 2002). In such a design, all children learn to focus on what, how and when they learn. They learn to plan, coordinate, regulate and control their own cognitive processes with a daily relooping of previously learned knowledge and skills and an explicit awareness building. As such, children with learning disabilities do not have to depend on implicit self-regulated learning, but all children benefit from the adjusted enhancement and adequate support of metacognitive knowledge and skills making them more active in their learning process and motivated to learn. In addition from PCM-perspective we know that learning might different in empathic children (or reactors), thinkers (or workaholics), persisters, dreamers, rebels and promoters. Each of these individuals is motivated differently and does different things when in distress. So within UDL it is important to motivate all these types in order to make all of them more aware of the need to process information adequately (Pauley & Pauley, 2012). If UDL is combined with PCM more children may learn to plan and regulate their thoughts, feelings and actions to deal adequately with information and solve efficiently the problems they encounter.

References

Ardila, A. (2013). Development of metacognitive and emotional executive functions in children. *Applied neuropsychology: Child*, 2, 82-87 doi:10.1080/21622965.2013.748388

Baddeley, A. (1986). *Working memory*. Oxford, UK: Clarendon Press.

Baddeley, A. (1996). Exploring the central executive. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology*, 49, 5-28. doi: 10.1080/027249896392784

Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences*, 4, 417-423.

Baddeley, A. D. (2002). Is working memory still working? *European Psychologist*, 7, 85-97.

Baddeley, A., Allen, R. J., & Hitch, G. J. (2010). Investigating the episodic buffer. *Psychologica Belgica*, 50, 223-243. doi: http://www.ingentaconnect.com/

Barbaresi, W. J., Katusic, S. K., Colligan, R. C., Weaver, A. L., & Jacobsen, S. J. (2005). Learning disorder: Incidence in a population-based birth cohort, 1976-82, *Rochester, Minn. Ambulatory Pediatrics*, 5, 281-289. doi: 10.1367/A04-209R.1

Barkley, R.A. (2001). The executive functions and self-regulations: an evolutionary neuropsychological perspective. *Neuropsychological Review*, 11(1), 1-29.

Bergmann, J., & Wimmer, H. (2008). A dual-route perspective on poor reading in a regular orthography: Evidence from phonological and orthographic lexical decisions. *Cognitive Neuropsychology*, 25, 653-676. doi: 10.1080/02643290802221404

Boekaerts, M., & Corno, L. (2005). Self-regulation in the classroom: A perspective on assessment and intervention. *Applied Psychology: An International Review*, 54(2), 199-231. doi: 10.1111/j.1464-0597.2005.00205.x

Boekaerts, M., Pintrich, P. R., & Zeidner, M. (Eds.). (2000). *Handbook of self-regulation.* San Diego, CA: Academic Press

Brown, A. L. (1980). Metacognitive development and reading. In R. J. Spiro, B. C. Bruce, & W. F. Brewer (Eds.), *Theoretical issues in reading comprehension* (pp. 453-481). Hillsdale, NJ: Erlbaum.

Brown, A.L. (1987). Metacognition, executive control, self-regulation and other more mysterious mechanisms. In: F.E. Weinert & R.H. Kluwe (Eds.). *Metacognition, motivation and understanding* (pp 65-116). Hillsdale, New Jersey: Laurence Erlbaum Associates.

Busato, V. V., Prins, F. J., Elshout, J. J., & Hamaker, C. (1998). Learning styles: A cross-sectional and longitudinal study in higher education. *British Journal of Educational Psychology*, 68, 427-441.

Callens, M., Tops, W., & Brysbaert, M. (2012). Cognitive Profile of Students Who Enter Higher Education with an Indication of Dyslexia. *Plos One*, 7. doi: 10.1371/journal.pone.0038081

De Clercq, A., Desoete, A., & Roeyers (2000). EPA2000: A multilingual, programmable computer assessment of off-line metacognition in children with mathematical-learning disabilities. *Behavior Research Methods, Instruments & Computers*, 32, 304-311.

Desoete, A., & Roeyers, H. (2002). Off-line metacognition. A domain-specific retardation in young children with learning disabilities? *Learning Disability Quarterly*, 25, 123-139. DOI:10.2307/1511279

Dermitzaki, I., & Efklides, A. (2003). Goal orientations and their effect on self-concept and metacognition in adolescence. Psychology. *The Journal of the Hellenic Psychological Society*, 10, 214-227.

Desoete, A. (2007a). Evaluating and improving the mathematics teaching-learning process through metacognition. *Electronic Journal of Research in Educational Psychology*, 5(3), 705-730.

Desoete, A. (2007b). Students with mathematical disabilities in Belgium: From definition, classification and assessment to STICORDI device. In T. E. Scruggs & M. A. Mastropieri (Eds.), *Advances in learning and behavioural disabilities: Vol. 20. International perspectives* (pp. 181-222). Oxford, England: Elsevier.

Desoete, A. (2008). Multi-method assessment of metacognitive skills in elementary school children: How you test is what you get. *Metacognition Learning*, 3, 189-206.

Desoete, A. (2009a). Mathematics and metacognition in adolescents and adults with learning disabilities. *International Electronic Journal of Elementary Education*, 2 (1), 82-100.

Desoete, A. (2009b). Metacognitive prediction and evaluation skills and mathematical learning in third-grade students. *Educational Research and Evaluation*, 15, 435-446.

Desoete, A. (2009c). The enigma of mathematical learning disabilities: Metacognition or STICORDI, that's the question. In D. J. Hacker, J., Dunlosky, & A. C. Graesser (Eds.), *Handbook of metacognition in education* (pp. 206-218). USA: Routledge.

Desoete, A. (2014). Cognitive predictors of mathematical abilities and disabilities. In R.. Cohen Kadosh & A. Dowker (Eds.), *The Oxford Handbook of Mathematical Cognition*. Oxford : Medicine UK. (pp.899-914).

Desoete, A. (2015). Predictive indicators for mathematical learning disabilities/dyscalculia in kindergarten children (pp 90-100). In S. Chinn (Ed)., *The International Handbook for Mathematical difficulties and Dyscalculia*. London & New York: Routledge.

Desoete, A., & De Weerdt, F. (2013). Can executive functions help to understand children with mathematical learning disorders and to improve instruction? *Learning Disabilities: A contemporary Journal*, 11 (2), 27-39.

Desoete, A., & Roeyers, H. (2002). Off-line metacognition. A domain-specific retardation in young children with learning disabilities? *Learning Disability Quarterly*, 25, 123-139.

Desoete, A., & Roeyers, H. (2006). Metacognitive macroevaluations in mathematical problem solving. *Learning and Instruction*, 16, 12-25.

Desoete, A., & Veenman, M. (Eds.). (2006). *Metacognition in mathematics education*. New York: NOVA.

De Weerdt, F., Desoete, A., & Roeyers, H. (2013a). Working Memory in Children with Reading and/or Mathematical Disabilities. *Journal of learning disabilities*, 46: 461-472.DOI: 10.1177/0022219412455238

De Weerdt, F., Desoete, A., & Roeyers, H. (2013b). Behavioral Inhibition in Children with Learning Disabilities, *Research in Developmental Disabilities*, 34, 1998-2007 DOI:10.1016/j.ridd.2013.02.020

Dignath-van Ewijk, C. (2011). Assessing students' acquisition of self-regulated learning skills using meta-analysis. In B. J. Zimmerman & D. H. Schunk (Eds.), *Handbook of self-regulation of learning and performance* (pp. 376-392).

Dignath, C., Buettner, G., & Langfeldt, H.-P. (2008). How can primary school students learn self-regulated learning strategies most effectively?: A meta-analysis on self-regulation training programmes. *Educational Research Review*, 3(2), 101-129. doi: 10.1016/j.edurev.2008.02.003

Efklides, A. (2008). Metacognition: Defining its facets and levels of functioning in relation to self-regulation and co-regulation. *European Psychologist*, 13, 277-287. http://dx.doi.org/10.1027/1016-9040.13.4.277

Flavell, J.H. (1976). Metacognitive aspects of problem-solving. In L.B. Resnick (Ed.), *The Nature of Intelligence* (pp. 231-236). Hillsdale, NJ: Erlbaum.

Fletcher, J. M., Francis, D. J., Morris, R. D., & Lyon, G. R. (2005). Evidence-based assessment of learning disabilities in children and adolescents. *Journal of Clinical Child and Adolescent Psychology*, 34, 506-522. doi: 10.1207/s15374424jccp3403_7

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology-General*, 133, 101-135. doi: 10.1037/0096-3445.133.1.101

Geary, D. C. (2011a). Cognitive predictors of achievement growth in mathematics: A 5-year longitudinal study. *Developmental Psychology*, 47, 1539-1552.

Geary, D. C. (2011b). Consequences, characteristics, and causes of mathematical learning disabilities and persistent low achievement in mathematics. *Journal of Developmental and Behavioral Pediatrics*, 32, 250-263.

Georghiades, P. (2007). Beyond conceptual change learning in science education: focussing on transfer, durability, and metacognition. *Educational Research*, 42, 119-139.

Hanna, E. I. (2005). *Inclusive design for maximum accessibility: A practical approach to universal design* (PEM Research Report No. 05-04). Upper Saddle River, NJ: Pearson Educational Measurement.

Harris, K. R., Graham, S., Brindle, M., & Sandmel, K. (2009). Metacognition and children's writing. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Handbook of metacognition in education* (pp. 131-153). New York: Routledge.

Hartman, H. & Sternberg, J. (1993). A broad BACIES for improving thinking. *Instructional Science*, 21, 401-425.

Hitchcock, C. G., Meyer, A., Rose, D., & Jackson, R. (2002). Providing new access to the general curriculum: Universal design for learning. *Teaching Exceptional Children*, 35, 8-17.

Kahler, T. (2004). *The Process Therapy Model.* Little Rock, AR: Taibi Kahler Associates.

Kahler, T. (2008). *The process therapy model: the six personality types with adaptations*. Little Rock: Taibi Kahler Associates, Inc.

Kruger, J. (2002). Unskilled and unaware – but why? A reply to Krueger and Mueller. *Journal of Personality and Social psychology*, 82, 189-192.

Kruger, J., & Dunning, D. (1999). Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. *Journal of Personality and Social Psychology*, 77, 1121-1134.

Koriat, A. (2007). Metacognition and consciousness. In P. D. Zelazo, M. Moscovitch, & E. Thompson (Eds.), *The Cambridge handbook of consciousness* (pp. 289-325). Cambridge, UK: Cambridge University Press.

Lucangeli, D., & Cornoldi, C. (1997). Mathematics and metacognition: What is the nature of the relationship? *Mathematical Cognition*, 3, 121-139.

Mazzocco, M. M. M., & Myers, G. F. (2003). Complexities in identifying and defining mathematics learning disability in the primary school-age years. *Annals of Dyslexia*, 53, 218-253. doi: 10.1007/s11881-003-0011-7

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, 41, 49-100. doi: 10.1006/cogp.1999.0734

Moore, A.M., Rudy, N.O., & Schcrat, M.H. (2015). Affect, motivation, working memeory, and mathematics. (pp. 918-936). In R.. Cohen Kadosh & A. Dowker (Eds.), *The Oxford Handbook of Mathematical Cognition*. Oxford : Medicine UK. (pp.917-936).

Nigg, J. T. (2000). On inhibition/disinhibition in developmental psychopathology: Views from cognitive and personality psychology and a working inhibition taxonomy. *Psychological Bulletin*, 126, 220-246. doi: 10.1037//0033-2909.126.2.220

OECD (2015). *The ABC of Gender Aduiality in Education:Aptitude, behaviour, confidence*. PISA, OECD Publishing. http://dx.doi.org/10.1787/9789264229945-en

Pauley, J.A., & Pauley, J.F. (2012). *Establishing a culture of patient safety. Improving communication, building relationships, and using quality tools*. ASQ quality press. Milwaukee, Wisconsin.

Pennington, B. F. (2006). From single to multiple deficit models of developmental disorders. *Cognition*, 101, 385-413. doi: 10.1016/j.cognition.2006.04.008

Pennington, B. F., Lemmon, L. S., Rosenberg, J., MacDonald, B., Boada, R., Friend, A., Leopold, D. R., Samuelsson, S., Byrne, B., Willcutt, E. G., & Olson, R. K. (2012). Individual Prediction of Dyslexia by Single Versus Multiple Deficit Models. *Journal of Abnormal Psychology*, 121, 212-224. doi: 10.1037/a0025823

Perfect, T. & Schwartz, B. (2002). *Applied Metacognition*. Cambridge: Cambridge University Press.

Pintrich, P.R. (2002). The role of metacognitive knowledge in learning, teaching, and assessing. *Theory Into Practice*, 41, 219-225.

Purvis, K. L., & Tannock, R. (2000). Phonological processing, not inhibitory control, differentiates ADHD and reading disability. *Journal of the American Academy of Child and Adolescent Psychiatry*, 39, 485-494. doi: 10.1097/00004583-200004000-00018

Rothbart, M.K. (1989). Temperament and development. In G. Kohnstamm, J. Bates, & M.K. Rothbartt (Eds.), *Temperament in childhood* (pp. 187-248). Chichester, UK: Wiley.

Rothbart, M.K. (2004). *Temperament and the pursuit of an integrated developmental psychology*. Merrill-Palmer Quarterly, 50 (4), 492-505

Rothbart, M. K., & Bates, J. (1998). Temperament. In W. Damon (Series Ed.) & N. Eisenberg (Vol. Ed.), *Handbook of child psychology: Vol 3. Social, emotional and personality development* (5th ed., pp.105-176). New York: Wiley.

Rubinsten, O., & Henik, A. (2009). Developmental Dyscalculia: heterogeneity might not mean different mechanisms. *Trends in Cognitive Sciences*, 13, 92-99. doi: 10.1016/j.tics.2008.11.002

Schraw, G. (1997). The effect of generalised metacognitive knowledge on test performance and confidence judgment. *Journal of Experimental Education*, 65, 135-147.

Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Science*, 26, 113-125.

Schraw, G. & Dennisson, S. (1994). Assessing metacognitive awareness. *Contemporary Educational Psychology*, 19, 460-475.

Schraw, G. & Nietfeld, J. (1998). A further test of the general monitoring skill hypothesis. *Journal of Educational Psychology*, 90, 236-248.

Schumacher, J., Hoffmann, P., Schmal, C., Schulte-Korne, G., & Nothen, M. M. (2007). Genetics of dyslexia: the evolving landscape. *Journal of Medical Genetics*, 44, 289-297. doi: 10.1136/jmg.2006.046516

Shalev, R. S., Manor, O., & Gross-Tsur, V. (2005). Developmental dyscalculia: a prospective six-year follow-up. *Developmental Medicine and Child Neurology*, 47, 121-125. doi: 10.1017/s0012162205000216

Sinkavich, F. J. (1995). Performance and metamemory: Do students know what they don’t know? *Instructional Psychology*, 22, 77-87

Tops, W., Callens, M. Desoete, A., Stevens, M., & Brysbaert, M. (2014). Metacognition for Spelling in Higher Education Students with Dyslexia: Is There Evidence for the Dual Burden Hypothesis?. DOI:10.1371/journal.pone.0106550 http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0106550

Tosto, M.G., Haworth, C.M.A., & Kovas, Y. (2015). Behavioural genomcs of mathematics. In R.. Cohen Kadosh & A. Dowker (Eds.), *The Oxford Handbook of Mathematical Cognition*. Oxford : Medicine UK. (pp.977-1001).

Vanderswalmen, R., Vrijders, J., & Desoete, A. (2010). Metacognition and spelling performance in college students. In Efklides, A., & Misailidi, P. (Eds.). *Trends and prospects in metacognition research* (pp. 367-394). New York: Springer.

Weinstein, C.E., Shculte, A.C., & Palmer, D.R. (2002) LASSI http://www.hhpublishing.com/_assessments/LASSI

Zimmerman, B.J., & Schunk, D.H. (2011). Self-regulated learning and performance: An introduction and an overview. In: B.J. Zimmerman & D.H. Schunk (Eds.). *Handbook of self-regulation of learning and performance* (pp. 1-12). New York: Routledge.

Veenman, M. V. J. (2005). The assesment of metacognitive skills: what can be learned from multi-method designs? In B. Moschner & C. Artelt (Eds.), *Lernstrategien und Metakognition: Implikationen für Forschung and Praxis*. Berlin: Waxmann.

Veenman, M.V.J. (2013, August). Metacognition and Learning: Conceptual and Methodological Considerations Revisited. What have we Learned During the Las t Decade? *Keynote at the15th biennial Conference of the European Association for Research on Learning and Instruction EARLI*, Munchen: Germany.

Veenman, M. V. J., & Elshout, J. J. (1999). Changes in the relation between cognitive and metacognitive skills during the acquisition of expertise. *European Journal of Psychology of Education*, XIV, 509-523.

Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning. Conceptual and methodological considerations. *Metacognition Learning*, 1, 3-14.

Waber, D. (2014). Paper in the symposium of L. Meltzer, R. Tannock and D. Waber. Understanding executive function and metacognition : implications for diagnosis and treatment of LD and ADHD at the 38th conference of the *International Academy for Research in Learning Disabilities* (IARLD) Vilnius Litouwen July 4h

Winne, P.H. (2011). A cognitive and metacognitive analysis of self-regulated learning. In: B.J. Zimmerman & D.H. Schunk (Eds). *Handbook of self-regulation of learning and performance* (pp. 15-32). New York: Routledge.

Ziegler, C. J., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: A psycholiguistic grain size theory. *Psychological Bulletin*, 131, 3-29.

Zimmerman, B. J. (2011). Motivational sources and outcomes of self-regulated learning and performance. In B. J. Zimmerman & D. H. Schunk (Eds.), *Handbook of self-regulation of learning and performance*. New York: Routledge.