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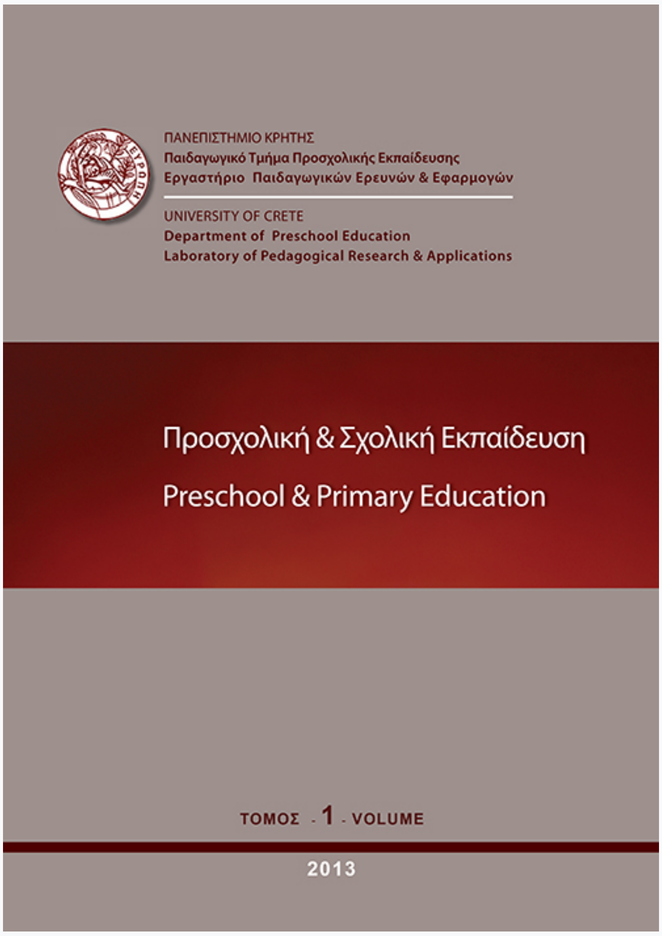


# PASS theory of intelligence in Greek: A review

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# PASS theory of intelligence in Greek: A review

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**Summary.** This article reviews the research focusing on the application of the PASS (Planning, Attention, Simultaneous, and Successive) neurocognitive theory of intelligence (Das, Naglieri, & Kirby, 1994) in Greek. Studies that have used the Greek version of the Cognitive Assessment System (CAS; Naglieri & Das, 1997) and PREP (PASS Reading Enhancement Program) are reviewed. It is concluded that when the research is taken as a whole, with regard to the content, quality, and results of the pertinent correlational and intervention studies, the applications of PASS theory yield similar results to those deriving from other populations who differ in cultural and linguistic characteristics. Implications for future research are discussed.

**Keywords:** PASS theory, cognition, intelligence, achievement

In modern societies, evidence-based diagnosis of different learning disorders is of paramount importance. This is particularly true when school systems and school professionals focus on the value of early identification and intervention. Learning disorders can significantly hamper attainment of personal, educational, and professional goals. However, their etiology may vary and their definition depends primarily on children's general aptitude for school learning. For instance, on the one hand, specific learning disabilities refer generally to unexpected low academic achievement, despite the provision of appropriate educational experiences. This low achievement may signal the presence of a disorder in basic psychological processes, such as attention, memory, and executive functioning (Papadopoulos, Panayiotou, Spanoudis, & Natsopoulos, 2005; Pennington, 2009) or phonological, orthographic processing and reading (Georgiou, Papadopoulos, Zarouna, & Parrila, 2012; Papadopoulos, Georgiou, & Kendeou, 2009). As the possibility of comorbidity–that is the situation where two or more psychological or educational disorders or syndromes occur together–is high (e.g., as high as 25-40% in children with reading disability and attention disorders; Willcutt & Pennington, 2000), it is particularly important to determine whether any one condition causes or is simply related to another. On the other hand, there are students who have the potential to demonstrate extraordinary performance in the areas of general intellectual ability, specific academic areas or creativity in schools, who usually go unidentified. As a result these students, who are generally defined as gifted, do not receive the services that they require beyond what is offered in the regular class curriculum. In either case, a comprehensive evaluation of cognitive functioning is necessary to discern the child's unique cognitive, linguistic or learning profile. To address this

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problem, one needs easily administrated and sensitive tests that can be used to identify affected individuals at different educational stages.

The present article reviews the research focusing on the application of the PASS (Planning, Attention, Simultaneous, and Successive) neurocognitive theory of intelligence (Das, Naglieri, & Kirby, 1994) in Greek, as an alternative approach to evidence-based diagnosis of different learning disorders. The application of PASS theory involves the use of the Cognitive Assessment System (CAS; Naglieri & Das, 1997) and PREP (PASS Reading Enhancement Program), for diagnostic and intervention purposes, respectively. The paper begins with a detailed description of the PASS theory and CAS, a short summary of the standardization process of CAS in Greek and continues with the review of the pertinent correlational and experimental studies.

## The PASS theory of intelligence

The PASS theory of intelligence (Das et al., 1994) is based largely on the neuropsychological work of Luria (1973, 1980). The maintenance of attention, the processing and storing of information, and the management and direction of mental activity comprise the activities of the operational units that work together to produce cognitive functioning (Das et al., 1994). Specifically, the PASS theory of intelligence proposes that cognition is organized in three systems, namely, the planning, the attention and arousal, and the processing systems and four processes, namely, Planning, Attention, Simultaneous and Successive processing (e.g., Naglieri & Das, 2005).

The first system is the *Planning* system, which involves executive functions responsible for regulating and programming behaviour, selecting and constructing strategies, and monitoring performance, and is located in the frontal cortex. The planning system, therefore, involves *solution planning and monitoring*, which involves developing and keeping track of a plan to solve a problem, and *plan execution*, which involves carrying out the plan. Papadopoulos, Parrila, and Das (2001) examined the outcomes and processes of planning and proposed that planning, as a frontal lobe function, involves four components, namely, problem representation, plan anticipation, plan execution, and solution evaluation. In turn, they proposed that the planning process can proceed either *in action* as a continuous cycle of refining representation, anticipating the outcomes, executing plans and subplans, and evaluating outcomes or *in advance* where participants execute a task linearly. In this latter case, participants build a representation of a given task, proceed to execute it, and finally, evaluate the end result. In this view, planning ability refers to a set of abilities including working memory, response inhibition, and error correction that are involved in goal-directed problem solving (see also Aguiar, Eubig, & Schantz, 2010; and Marcovitch & Zelazo 2009, for a similar argument).

The second system, the *Attention* system refers to the ability to demonstrate focused, selective, sustained, and effortful activity over time and resist distraction, and is located in the brain stem and lower cortex. Focused attention refers to the type of cognitive functioning in which engaged concentration on a specific object or activity is observed. This type of processing might be automatic or effortless attention, governed by the attention/arousal system or cortical tone (Kirby & Williams, 1998) or conscious and effortful attention (Quay, 1988). While attention (for e.g., selective or sustained) is mainly under voluntary control, it is influenced by cortical arousal. Selective attention refers to the ability to focus on the relevant aspects of stimuli while screening out the irrelevant ones. Sustained attention, in turn, refers to the ability to maintain the mental focus of attention over an extended period of time on a specific issue, object or task (Posner & Boies, 1971). In his hybrid model of executive functions, Barkley (1997) integrates this type of processing under the notion of behavioural inhibition[1]. However, after a careful review of the relevant European research, Das and Papadopoulos (2003) suggested that behavioural inhibition deficit can be better considered as a characteristic only of the clinic-referred children with hyperactivity or ADHD (Attention Deficit Hyperactivity Disorder), rather than as a characteristic of the general population of children with hyperactivity or ADHD.

The third functional unit includes *Simultaneous* and *Successive coding* of information and is located in the posterior (occipital, parietal, and temporal) cortex. Simultaneous processing involves the arrangement of incoming information into a holistic pattern, or a gestalt, that can be "surveyed" in its entirety. For example, recognition of whole words by sight involves this kind of processing, as does comprehension of the meaning of a sentence or a paragraph (Kendeou, Papadopoulos, & Spanoudis, in press). In addition, simultaneous processing is necessary in performing tasks tapping orthographic knowledge (Wang, Georgiou, & Das, 2012) and visual-spatial reasoning abilities, such as matrix reasoning (e.g., Raven's Progressive Matrices; see Raven, 2000) and block design test (from WISC-III; Wechsler, 1992). For this reason, simultaneous processing tasks usually require both nonverbal and verbal processing in order to be successfully solved. Successive processing, in turn, refers to coding information in discrete, serial order where the detection of one portion of the information is dependent on its temporal position relative to other material. It is used in skills such as word decoding and spelling where maintaining the exact sequence or succession of letters in the word is crucial for completion (Das, 2002; Naglieri, 2001; Papadopoulos, 2001, 2002). Thus, successive processing predicts reading through the effects of phonological memory, as it includes the perception of stimuli in sequence and the linear execution of sounds (Papadopoulos, 2001; Papadopoulos, Charalambous, Kanari, & Loizou, 2004). In this view, simultaneous and successive processing is involved with the acquisition, storage, and retrieval of knowledge according to the tasks' demands.

These functional units are all related while at the same time they maintain independence by having distinct functions. In addition, all processes are influenced by knowledge base and thus, the integration of knowledge is important for effective processing to be accomplished (Das et al., 1994). For the present purposes, it is examined (a) how these processes are effectively operationalized through the use of the CAS, (b) how they relate to cognition and achievement, and (c) how PASS theory provides a comprehensive framework to understand and identify exceptional children.

## The Cognitive Assessment System

The operationalization of the PASS theory of intelligence has been based on the identification of tests that are consistent with the process of interest. The tasks were developed and validated through extensive research and on the basis of their correspondence to the theoretical framework. These four processes are assessed by Das-Naglieri Cognitive Assessment System (DN-CAS; Naglieri & Das, 1997). To meet the administrator's need for flexibility, the CAS includes two forms, a Standard Battery and a Basic Battery. Each of the two forms is composed of the PASS scales. In the Standard Battery, these scales are composed of three subtests each (12 subtests). In the Basic Battery, the scales are composed of two subtests each (8 subtests).

More specifically, the CAS is organized into three levels: (1) the Full Scale, an overall measure of cognitive functioning, (2) the Planning, Attention, Simultaneous, and Successive cognitive processing scales, which represent the individual's cognitive functioning and are used in identification of specific strengths and weaknesses in cognitive processing, and (3) the Subtests, which are appropriate for assessing cognitive processes underlying learning problems (see CAS Interpretive Handbook; Naglieri & Das, 1997). The major scales are as follows: (a) Planning [subtests: Matching Numbers (MN), Planned Codes (PCd), Planned Connections (PCn)], (b) Attention [subtests: Expressive Attention (EA), Number Detection (ND), Receptive Attention (RA)], (c) Simultaneous processing [subtests: Nonverbal Matrices (NvM), Verbal-Spatial Relations (VSR), Figure Memory (FM)], and (d) Successive processing [subtests: Word Series (WS), Sentence Repetition (SR)–replaced by Sentence Questions (SQ) in ages 8-17, and Speech Rate (SpR)].

Test administration and scoring varies among the scales depending on task demands, including accuracy and speed of response as dependent variables. There are subtests, such as MN, PCd, EA, ND, RA, for example, in which scoring begins with recording the time and number correct (accuracy score) for each item. These are combined into ratio scores obtained using a look-up table provided in the Record Form. The ratio scores, then, are summed across items to obtain the subtest raw scores which are converted to the subtest scaled score. This is the participant's efficiency score. In the next set of subtests, the PCn and SpR, scoring is the time needed to complete the item sequence correctly. Finally, the scoring for the subtests NvM, VSR, FM, WS, SR (and SQ) is the total number of items correctly answered.

The profile derived from these scales is an essential part of the diagnosis type. The subtest summary profile provides percentile scores that allow the clinician to evaluate the individual's relative strengths and weaknesses in the four different scales and overall against the standardization sample and to assess recovery patterns over time.

The CAS has been standardized in Greek (CAS-GR; Papadopoulos, Georgiou, Kendeou, & Spanoudis, 2008). In this process, both the adaptation method and the selection and measurement of a normative sample, essential to the test development, were carefully considered. Quality control procedures relating to (a) the adaptation of source language items into the target language, (b) the translation/adaptation of test instructions, (c) the development of additional items for the target language, (e) the selection of the participants across ages, gender, parental educational level, and geographical region in order to represent the norms of the Greek population in Cyprus, and (f) the training of the examiners who collected the data were taken into account. As a result, the standardized CAS in Greek yields similar factor structures to those of the original American sample, suggesting that the CAS subtests measure the PASS neurocognitive abilities similarly between the Greek and the American groups. The next sections review a number of studies that have used PASS theory and CAS in Greek. The review is organized into four categories: studies on reading development, studies on reading disability subtypes and possible comorbidities, studies on attention and planning, and intervention studies.

## Studies using PASS theory and CAS in Greek

The CAS can be used to facilitate mental health professionals in the identification of specific learning disabilities, such as dyslexia and math disabilities, Attention Deficit Hyperactivity Disorder (ADHD), giftedness, and mental retardation. To date, Greek CAS has been used in a number of studies (Table 1) focusing on the differential diagnosis and the study of the cognitive profiles of children with specific learning disabilities (e.g., Papadopoulos, Georgiou, & Parrila, 2012), attention and planning deficits (e.g., Papadopoulos et al., 2005), reading comprehension deficits (e.g., Papadopoulos, Kendeou, & Shiakalli, 2013) as well as of precocious readers (Papadopoulos, Kendeou, Ktisti, & Fella, 2013). CAS subtests have been also used in correlational studies examining the cognitive correlates of reading (e.g., Papadopoulos, 2001), reading and math (e.g., Georgiou, Tziraki, Manolitsis, & Fella, 2013), orthographic processing (Papadopoulos & Georgiou, 2010) and reading comprehension (e.g., Kendeou, Papadopoulos, & Spanoudis, 2012). In addition, CAS subtests, such as the Non-Verbal Matrices, have been included in the selection measures in (a) standardization (e.g., Papadopoulos, Spanoudis, & Kendeou, 2009) or (b) longitudinal (e.g., Papadopoulos, Kendeou, & Spanoudis, 2012) studies, focusing on the measurement and conceptualization of reading related skills, as phonological ability.

In addition, in several studies, CAS subtests have been administered along with other ability or intelligence tests, such as, the Wechsler Intelligence Scale for Children and/or a set of executive planning and theory of mind tasks (WISC-III, Wechsler, 1992; e.g., Papadopoulos et al., 2005; Papadopoulos & Panayiotou, 2007), selected verbal ability subtests from the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI, Wechsler, 1990; e.g., Papadopoulos, Charalambous, Kanari, & Loizou, 2004), the Dyslexia Early Screening Test-2 (DEST-2; Nicolson & Fawcett, 2004[2]; e.g., Papadopoulos & Kendeou, 2010) and/or the Dyslexia Screening Test (DST-J; Fawcett & Nicolson, 2004[3]; e.g., Papadopoulos, Constantinidou, & Douklias, 2010), and a set of phonological ability, word reading, orthographic processing, naming speed, and reading comprehension measures from the Early Reading Skills Assessment Battery (ERS-AB; Papadopoulos, Spanoudis, & Kendeou, 2008; e.g., Papadopoulos, Kendeou et al., 2013; Kendeou & Papadopoulos, 2012; Papadopoulos, 2001; Papadopoulos, Georgiou, & Kendeou, 2009), following the specific aims of each study. In all instances, the examination of the relationships between CAS cognitive processing measures, intelligence, achievement, and other cognitive and linguistic tests helped to establish the validity of the CAS as a predictor of academic and cognitive performance. A few of these studies are presented selectively in the section that follows to provide evidence for the obtained critetion-related validity of the CAS in Greek.

## Studies on reading development

To date, the CAS-GR has been mostly used in studies examining typical and atypical reading development in Greek. In the case of typical reading development, the role of successive and simultaneous processes has been examined within the framework of proximal and distal processes to reading, initially proposed by Das et al. (1994) and tested by Das, Parrila, and Papadopoulos (2000). Our findings from Greek-speaking populations support the above framework of reading development. Specifically, it has been found that although both phonological and other cognitive processes are central for the development of early reading skills, phonological processes are firmly proximal to reading, whereas other processes relevant to processing efficiency and capacity, such as successive processing (which includes elements of short-term memory and working memory, naming time, and articulation speed) and simultaneous processing (which is related to the development of letter recognition and later orthographic coding skills), are mostly distal to reading development (Papadopoulos & Georgiou, 2000; Papadopoulos, 2001). In short, tasks used to tap successive processing and in particular SpR and SR subtests, and tasks used to tap simultaneous processing, in particular VSR and FM, have been found to strongly correlate with word decoding (Papadopoulos, 2001), orthographic processing (Papadopoulos & Georgiou, 2010), and reading comprehension (e.g., Kendeou et al., 2012).

**Table 1** Studies using PASS theory and CAS in Greek

| | Study Properties | | | | | | |
|---|---|---|---|---|---|---|---|
| Study | Type of Study | Methodology/ Analysis | N | Groups | Ages/Grades | CAS Tasks Used | Main Findings |
| *Studies on Reading Development* | | | | | | | |
| Papadopoulos, Kendeou & Spanoudis (2012) | Correlational, Longitudinal | Structural Equation Modeling | 280 | Standardization Group | Kindergarten through Grade 2 | NvM (control) | NvM is a robust indicator of non-verbal ability |
| Papadopoulos, Spanoudis, & Kendeou (2009) | Correlational, Longitudinal | Item Response Theory | 280 | Standardization Group | Kindergarten & Grade 1 | NvM (control) | NvM is a robust indicator of non-verbal ability |
| Kendeou, Papadopoulos, & Spanoudis (2012) | Correlational, Longitudinal | Structural Equation Modeling | 286 | Randomly Selected Sample | Grade 1 & Grade 2 | NvM (control); VSR, SRQ | Reading comprehension tests, such as WJPC and a Recall test, exert processing demands on VSR & SRQ along with orthographic processing |
| Kendeou & Papadopoulos (2012) | Correlational, Longitudinal | Structural Equation Modeling | 280 | Randomly Selected Sample | Grade 1 & Grade 2 | VSR, SRQ, SpR | Information processing skills do not significantly predict performance on CBM-Maze |
| Papadopoulos, Kendeou, & Shiakalli (2013) | Longitudinal | Group comparisons | 213 | WJPC-Low; CBM-Maze-Low; Recall-Low; Control-No Deficit- groups | Kindergarten through Grade 2 | NvM (control); CAS Basic Battery (8 subtests) | When different reading comprehension tests are used as diagnostic tools, as opposed to the use of component skills, the between-group differences on cognitive skills are minimized |

**Table 1** Continued

| | Study Properties | | | | | | |
|---|---|---|---|---|---|---|---|
| Study | Type of Study | Methodology/ Analysis | N | Groups | Ages/Grades | CAS Tasks Used | Main Findings |
| Kendeou, Papadopoulos, & Spanoudis (in press) | Correlational, Cross-sectional | Structural Equation Modeling | 455 | Randomly Selected Sample | Grades 7 through 12 | NvM (control); CAS Basic Battery (8 subtests) | Planning and Attention emerge as stronger correlates of reading comprehension than information processing skills in adolescence |
| Papadopoulos & Kendeou (2013) | Correlational, Cross-sectional | Structural Equation Modeling | 456 | Randomly Selected Sample | Grades 7 through 12 | NvM (control); CAS Basic Battery (8 subtests) | Planning and Attention alongside fluency skills predict performance on CBM-Maze, whereas Simultaneous processing alongside orthographic processing and fluency skills predict performance on text-reading fluency |
| Papadopoulos (2001) | Correlational | Regression | 100 | Randomly Selected Sample | Grade 1 | CAS Standard Battery (12 subtests) | Successive processing predicts reading accuracy in Grade 1 in Greek, with its effect mediated by PA |
| Papadopoulos & Georgiou (2010) | Correlational, Cross-sectional | Regression | 355 | Randomly Selected Sample | Kindergarten through Grade 2 and Grade 4 through Grade 6 | Successive & Simultaneous processing subtests | Cognitive & linguistic factors accounted for unique variance in orthographic processing |
| Papadopoulos, Kendeou, Ktisti, & Fella (2013) | Longitudinal | Group comparisons | 62 | Precocious readers; Typically developing readers | Kindergarten through Grade 2 | CAS Basic Battery (8 subtests) | A cognitive advantage (specific to precocious readers' simultaneous processing ability) followed in development the linguistic advantage |

**Table 1** Continued

| Study | Study Properties: Type of Study | Methodology/ Analysis | N | Groups | Ages/Grades | CAS Tasks Used | Main Findings |
|---|---|---|---|---|---|---|---|
| Georgiou, Manolitsis, & Tziraki (in press) | Longitudinal | Regression | 90 | Randomly Selected Sample | Kindergarten through Grade 1 | 1 measure from each CAS subscale (PCd, RA, NvM, WS) | Reading ability was predicted by successive processing and planning; none of the PASS processes predicted math ability |
| *Reading Disability Subtypes and Possible Comorbidities* | | | | | | | |
| Papadopoulos, Georgiou, & Kendeou (2009) | Longitudinal | Group comparisons; Regression | 242 | Double-deficit; Phonological deficit; Naming deficit; Control-No Deficit-groups | Kindergarten through Grade 2 | NvM (control) | NvM is a robust indicator of non-verbal ability |
| Chatzoudi & Papadopoulos (2013) | Longitudinal | Group comparisons | 84 | Poor readers/poor spellers; Poor readers/good spellers; Good readers/poor spellers; Good readers/good spellers groups. | Kindergarten through Grade 2 | NvM (control); SVR, FM, SR, SpR | Only Poor readers/poor spellers group showed deficits at information processing level (alongside linguistic deficits) |
| Papadopoulos, Constantinidou, & Douklias (2010) | Longitudinal | Group comparisons | 175 | RD group; ADD group, RD+ADD group (comorbid); Control-no-Deficit group | Kindergarten through Grade 2 | NvM (control); CAS Basic Battery (8 subtests) | CAS subtests alongside linguistic measures can reliably identify children with RD, ADD, or comorbid deficits |
| Spanoudis, Papadopoulos, & Spyrou (2013) | Experimental | Group comparisons | 140 | RD group; SLI group, RD+SLI group (comorbid); Control-no-Deficit group | Grade 2 & Grade 4 | NvM (control); SRQ, FM | CAS subtests alongside linguistic measures can reliably identify children with RD, SLI, or comorbid deficits |

**Table 1** Continued

| Study | Study Properties | | | | | | |
|---|---|---|---|---|---|---|---|
| | Type of Study | Methodology /Analysis | N | Groups | Ages/Grades | CAS Tasks Used | Main Findings |
| Papadopoulos, Georgiou, & Parrila (2012) | Correlational, Cross-sectional | Group comparisons | 202 (Study I) 160 (Study II) | Randomly Selected Sample (Study I) 3 groups of children with dyslexia and 3 groups of CA-matched typically developing readers (Study II) | Grade 4 (Study I) Grade 2, Grade 4, & Grade 6 (Study II) | ND subtest from CAS (control) | Individual differences on attention (as well as on verbal & non-verbal ability) are among those extraneous variables, primarily responsible of the rather mixed pattern of results on beat perception deficits |
| *Studies on Attention and Planning* | | | | | | | |
| Papadopoulos, Panayiotou, Spanoudis, & Natsopoulos (2005) | Experimental | Groups comparisons | 98 | ADD & Control-no-Deficit Groups | Grade 4 & Grade 6 | NvM (control); Attention subtests (EA, ND, RA) & Crack-the-Code (EF task) | The failure of ADD children on cognitive performance measures is linked to planning impairments. The co-occurrence of anxiety did not interact with inattention to affect planning performance |
| Papadopoulos & Panayiotou (2007) | Correlational | Factor analysis; Group comparisons | 258 | Randomly Selected Sample divided to ADD and Control-no-Deficit groups | Grade 4 | Attention subtests (EA, ND, RA) alongside ACL screening device | ACL scores were positively correlated with scores on the cognitive measures of attention |
| Papadopoulos, Giorgatsos, Kritiotou, & Panayiotou (2013) | Correlational | Structural Equation Modeling | 114 | ADD & ADHD groups | Grade 1 | CAS Basic Battery (8 subtests) | PASS components along with speed of processing and behavioral inhibition can reliably discriminate ADD from ADHD |

**Table 1** Continued

| Study | Study Properties | | | | | | |
|---|---|---|---|---|---|---|---|
| | Type of Study | Methodology/ Analysis | N | Groups | Ages/Grades | CAS Tasks Used | Main Findings |
| *Implications for Intervention* | | | | | | | |
| Papadopoulos, Charalambous, Kanari, & Loizou (2004) | Intervention; Longitudinal | Group Comparisons | 30 | Children at-risk for reading difficulties and a Control-no-Deficit group | Kindergarten through Grade 1 | Successive & Simultaneous processing subtests | Significant effects for all cognitive and linguistic measures; Participants benefited most from PREP remediation had somewhat better initial successive processing skills |
| Papadopoulos & Kendeou (2010) | Intervention; Longitudinal | Group Comparisons | 77 | 2 experimental groups with reading difficulties (assigned to PREP and DEST-RT treatments); a RA-Control; a CA-control | Kindergarten through Grade 1 | Successive & Simultaneous processing subtests | Remediation benefits are maximized when children's profiles are identified prior to assigning them to remedial programs |
| Ktisti & Papadopoulos (2013) | Intervention; Longitudinal | Group Comparisons | 56 | 4 experimental groups with reading difficulties (assigned to PREP; GG or the two combined); and a Control-no-Deficit group | Kindergarten through Grade 2 | CAS Basic Battery (8 subtests) | Cognitive remediation remains superior to phonological training; Combined treatments provided modest advantages for cognitive skills (particularly for successive processing) |

*Note*: PASS=Planning, Attention, Simultaneous, and Successive processing theory; CAS = Cognitive Assessment System; PCd = Planned Codes; EA = Expressive Attention; ND = Number Detection; RA = Receptive Attention; NvM = Non-Verbal Matrices; VSR = Verbal-Spatial Relations; FM = Figure Memory; WS = Word Series; SRQ = Sentence Repetition & Questions; SpR = Speech Rate; PA = Phonological Awareness; WJPC = Woodcock-Johnson Passage Comprehension; CBM-Maze = Curriculum-Based Measurement-Maze; ADD = Attention Deficit Disorder; ADHD = Attention Deficit Hyperactivity Disorder; RD = Reading Difficulties; SLI = Specific Language Impairments; CA-C = Chronological Age-matched; RA-C = Reading Age-Matched; EF = Executive Functioning; ACL = Attention Checklist; PREP= PASS Reading Enhancement Program; GG = Graphogame; DEST-RT = Dyslexia Early Screening Test-Remedial Tool.

With regard to reading comprehension, Kendeou and Papadopoulos (2012), and Kendeou, Papadopoulos, and Spanoudis (2012) investigated, in the early elementary years, the relative contribution of different reader skills, namely, cognitive (PASS processes), phonological, rapid automatized naming, orthographic, and reading fluency skills, in reading comprehension developmentally and for different reading comprehension tests: the Woodcock-Johnson Passage Comprehension (WJPC; Woodcock, McGrew, & Mather, 2001), the Curriculum Based Measurement-Maze test (CBM-Maze; Deno, 1985), and a recall test based on Causal Network Theory (van den Broek, 1990). The findings from structural equation modelling (SEM) showed that the three reading comprehension tests pose different processing demands to the young reader. Specifically, the WJPC test exerts processing demands predominantly on orthographic processing and working memory skills (as defined by VSR and SRQ CAS measures). The CBM-Maze test exerts processing demands on fluency and vocabulary skills, whereas the Recall test exerts processing demands on phonological processing, orthographic processing, and working memory skills. When the contribution of each skill was separately and systematically examined, the findings showed that the relative contribution of WM, fluency, orthographic processing, and phonological skills differed across the three tests, whereas the contribution of vocabulary and RAN were not significant. The finding that commonly used tests of reading comprehension may not tap the same array of language and cognitive processes suggests that the identification of struggling readers when using these tests results in different profiles of readers. Consequently, knowing which test is used and the skills contributing to it is critical for the design of remedial instruction. More importantly, with regard to the role of the PASS processes, these emerged as significant predictors of WJPC and Recall tests on which performance depends predominantly on decoding (Francis et al., 2006) and working memory (Swanson & O'Connor, 2009). Thus, PASS processes are necessary for the reader to be engaged in connection-building during reading and the construction of a coherent mental representation of the text.

Papadopoulos, Kendeou, and Shiakalli (2013) investigated further this possibility. Specifically, they examined retrospectively the reading profiles across several literacy-related measures of a group of 213 children from Kindergarten to Grade 2, aiming to provide answers about the developmental profiles of poor comprehenders in the early years of schooling. In doing so, the authors used different reading comprehension tests (such as the WJPC, CBM-Maze, and a Recall task) as diagnostic tools, as opposed to the use of component skills, in order to define the groups of poor comprehenders. Papadopoulos et al. hypothesized that this approach would result in groups of poor readers with different profiles, beyond those that are usually identified within traditional reading frameworks such as the Simple View of Reading (SVR; Gough & Tunmer, 1986) model. Differences among poor reading comprehension groups were explored on a large range of linguistic and cognitive skills. With regard to linguistic skills, measures of letter knowledge, word decoding, phonological processing, RAN, orthographic processing, and spelling were included. With regard to cognitive skills, measures of planning, attention, simultaneous, and successive processing skills were included. Results showed that the CBM-Maze-Low group exhibited relatively low performance on most linguistic component skills such as RAN, phonological ability, word reading fluency and accuracy, across all three time points. The WJPC-Low and the Recall-Low groups, in contrast, tend to consist of readers who perform relatively low on word reading fluency and phonological measures only, in Grades 1 and 2, but not in Kindergarten. None of the groups of poor readers showed any cognitive deficits compared to their typical counterparts. This is not surprising given that groups were formed on the basis of their performance across different reading comprehension tests of varying cognitive processing demands. It is possible that this approach minimized the between-group differences in cognitive skills. The authors concluded that these results can be explained in part by a careful analysis of the component processes decoding depends upon, and the age of the participants.

In fact, Kendeou, Papadopoulos, and Spanoudis (in press) provided further empirical evidence for both of these accounts, examining the extent to which the four PASS components, namely, Planning, Attention, Simultaneous, and Successive processing predict performance on the CBM-Maze test (Deno, 1985) in adolescence. Using SEM, the findings from this initial attempt to directly link the four PASS processes and reading comprehension in adolescence supported the main hypothesis put forward by the authors, namely, that as the demands of the reading task increase, so does the relevance of the four PASS processes. Because lower-level or bottom-up reading skills have been mastered in early years, the relevance of Successive and Simultaneous processing that support those skills is limited or it is mostly evident through phonological and orthographic processing, respectively. The relevance of Planning and Attention, in contrast, is strong because these processes support higher-order or top-down reading comprehension; the kind of processes that are demanded by longer and more complex texts that are typical readings in this age group. When Papadopoulos and Kendeou (2013) examined the extent to which the four PASS components predict performance on the CBM-Maze and text-reading fluency in adolescence, they reached similar conclusions: planning and attention along with word reading fluency skills predicted performance on the CBM-Maze test. In turn, simultaneous processing emerged as a reliable predictor of performance in text reading fluency, along with orthographic processing and word reading fluency skills. These results further elucidate the role of the four PASS processes, emphasising that the underlying skills that support reading performance in adolescence are relatively stable and seem to centre on the quality of students' planning and attention skills, as well as on simultaneous processing – along with word fluency and orthographic processing – depending on task demands.

That successive and simultaneous processing is important in earlier years is also supported by comparable findings on the longitudinal prediction of reading and orthographic processing performance in elementary school years. For example, Papadopoulos (2001) showed that Speech Rate, Sentence Repetition, and Word Series (indicators of successive processing) predicted reading accuracy (Word Identification and Word Attack) in Grade 1 in Greek, with their effect being mediated by phonological awareness. In turn, Papadopoulos and Georgiou (2010) showed that both cognitive (successive and simultaneous processes) and linguistic (phonological ability and naming speed) factors accounted for unique variance in the orthographic processing measures (Orthographic Choice and Word Chains) in both concurrent and longitudinal analyses in Grades 1 through 6.

In a somewhat different vein, Papadopoulos et al. (2013) investigated the role of linguistic and cognitive processes in reading precocity from Kindergarten to Grade 2. Until recently, reading precocity had been studied only with a particular focus on the linguistic factors that may contribute to it. As a result, there was converging evidence, that phonological awareness, letter naming, and reading fluency are significant predictors of excellence in reading achievement before formal reading instruction begins, irrespective of the orthographic transparency of the language (e.g., Stainthorp & Hughes, 1998; Tafa & Manolitsis, 2008). However, the contribution of cognitive skills that might explain some of the individual differences with regard to reading precocity had been overlooked. Papadopoulos et al. demonstrated that precocious readers exhibited a cognitive advantage over their typical developing peers, as well as a linguistic advantage. What is more, results showed that a cognitive advantage (specific to precocious readers' simultaneous processing, that is, the ability to integrate stimuli into groups) followed the linguistic advantage in development. These findings highlighted both the importance of studying the development of precocious readers apart from that of struggling readers, and the need to use reading programs that place explicit emphasis on both linguistics and cognitive skill development.

Finally, Georgiou, Manolitsis, and Tziraki (in press) examined whether the findings on the role of PASS processes in predicting early reading could be generalized in the prediction of early mathematics ability. In doing so, Georgiou et al. administered the basic set of the CAS subtests along with a set of phonological awareness and visuo-spatial working memory tasks to eighty-three Greek children at the beginning of Kindergarten. At the end of Kindergarten and Grade 1, participants were assessed on reading and mathematics. Results showed that with regard to reading ability (as measured by real word and non-word reading fluency), successive processing contributed to the prediction of reading ability beyond the variance accounted for by phonological awareness and visuo-spatial working memory. In addition, planning emerged as the unique predictor of reading ability, a finding that speaks for the ancillary role of the distal cognitive processes in reading. Specifically, at this early stage of reading, where word fluency is important, planning seems to allow the reader to define a word's identity that distinguishes it from other similarly spelled words (Papadopoulos, 2002). In contrast, none of the PASS processes accounted for unique variance in mathematics. The authors concluded that in very young ages the contribution of PASS cognitive processes is rather domain-specific.

In sum, research focusing on the role of the PASS processes in reading development in Greek produces some very clear findings. First, in early years, successive and simultaneous processing are strong correlates of word reading and orthographic processing, respectively. Second, both become less important in adolescence, a time when planning and attention emerge as more reliable predictors of reading comprehension. Finally, when it comes to reading assessment, the PASS cognitive operations that are involved in reading performance depend also on task demands. The next section focuses on the different cognitive processing patterns that may distinguish between different types of learning disabled children.

## Reading disability subtypes and possible comorbidities

With regard to the study of atypical reading development and dyslexia, a number of longitudinal projects that utilized the CAS have aimed to contribute to at least three areas: (a) to the assessment of reading difficulties and dyslexia, delving into the potential cognitive or neuropsychological explanations of the disorder, (b) to the discussion of associated impairments and comorbid learning disabilities, and (c) to the development of remedial treatment techniques relying largely on an aptitude-treatment interaction approach. Starting from these premises, a number of studies have focused on how different component skills relevant to reading and spelling performance and the neuropsychological factors underpinning them can be studied simultaneously to substantially increase the understanding of the disorder being manifested.

Specifically, different subgroups of children exhibiting reading difficulties have been examined with the use of specific CAS subtests. For example, Papadopoulos, Georgiou, and Kendeou (2009) examined longitudinally the double-deficit hypothesis in Greek following a group of children from Kindergarten to Grade 2. In doing so, four groups were formed on the basis of two composite scores of phonological and naming-speed criterion measures, namely, a double-deficit group (DD), a phonological deficit (PD) group, a naming deficit (ND) group, and a control group exhibiting no deficits (CnD). To ensure that phonological or naming-speed deficits are not confounded with intelligence deficits, the effects of nonverbal ability, measured with the Non-Verbal Matrices test from the CAS and of verbal ability (measured with 2 verbal tasks from WISC-R) were controlled among the groups.

Results showed that the DD group exhibited greater dysfunction in reading and orthographic processing compared to the single deficit and CnD groups. Also, although the three deficit groups were not easily differentiated in Kindergarten, their differences were maximized in Grade 1 and remained the same in Grade 2. The type and severity of reading deficits found in the ND group were mostly associated with naming speed at both the word- and text-reading levels, deficits that persisted across development. Finally, the PD group showed mostly deficient orthographic and poor decoding skills that improved across development. In a nutshell, controlling the effects of intelligence is necessary when testing the cognitive and linguistic profiles of subgroups of children with reading difficulties or dyslexia (Shaywitz, Mody, & Shaywitz, 2006). The results of this and other similar studies (see below) suggest that the use of the Non-Verbal Matrices as part of the selection measures is adequate to control for the effects of the so-called nonverbal intellectual potential of children with reading difficulties.

Research to date has shown robust correlations between disabilities in reading and spelling, but it has not examined how reading and spelling skills develop among young learners of varying reading and spelling ability or how these various groups of young learners differ with regard to their cognitive and linguistic profiles. Chatzoudi and Papadopoulos (2013) reported data in this respect by examining four groups of young learners, formed on the basis of two composite scores of word fluency and spelling criterion measures: (a) poor readers/poor spellers (PrPs), (b) poor readers/good spellers (PrGs), (c) good readers/poor spellers (GrPs), and (d) good readers/good spellers (GrGs) groups. The groups were identified in Grade 2 and compared retrospectively in Kindergarten and Grade 1 on the criterion measures, as well as on word-reading accuracy, phonological processing, and naming speed, in addition to information processing abilities and planning, using CAS measures. As in previous research, the effects of verbal and nonverbal ability (using NvM test), age, gender, and SES were controlled among the groups. Results showed that the PrPs group exhibited significantly low performance in reading and spelling skills across all three time points. Also, group differences were more profound in Grade 1 and Grade 2 than in Kindergarten. The poor performance of the PrGs group was mostly associated with phonological and naming deficits, whereas poor performance of the GrPs group was mostly associated with speed deficits at text-reading level. Finally, only the PrPs group showed added deficits at the information-processing level, on both successive and simultaneous tasks. This result indicates that cognitive deficits at the information-processing level are more likely to be profound in children with severe reading and spelling deficits in Greek.

Papadopoulos et al. (2010) also examined the possible incidence of comorbidity of reading difficulties and attention deficits (ADD) in Kindergarten through Grade 2. Four groups were formed on the basis of two composite scores of reading fluency and attention criterion measures (using the EA, RA, and ND subtests from the CAS in the latter case): a Comorbidity Deficit group, exhibiting reading and attention deficits, a Reading Disability group, an Attention Deficit group, and a Control group exhibiting no deficits. The four groups were identified in Grade 1 and they were compared from Kindergarten to Grade 2 on a set of cognitive (the remaining CAS subtests, that is the planning, simultaneous, and successive processing tasks), phonological processing, RAN, sensorimotor, word reading fluency and accuracy, orthographic processing, and passage comprehension measures. Results showed that CAS subtests, when used along with a set of linguistic measures, can reliably identify children with attention disorders and/or reading difficulties with a remarkably high predictive accuracy (98%) already at age 6. The type and severity of attention deficits found in the ADD group were mostly associated with planning deficits that persisted across development. Naming deficits (in non-alphanumeric tasks) were also observed for this group in Grade 1. The type and severity of reading deficits found in the RD group were mostly associated with phonological, naming, and successive processing deficits, with the former two deficits persisting across development. Finally, the comorbid group exhibited a different pattern of correlates rather than an additive combination of the correlates of each disorder, a finding coinciding with the presence of a cognitive subtype (with comorbidity standing as a third independent disorder; see Rucklidge & Tannock, 2002 for a thorough discussion).

Expanding on this line of research, Spanoudis, Papadopoulos, and Spyrou (2013) investigated the possible incidence of comorbidity of reading difficulties (RD) and specific language impairments (SLI). The results were equally promising as far as the identification of the groups is concerned. The cognitive profile of the comordid group did not share the same etiological risk factors with the RD and the SLI groups. The comorbid group was particularly impaired in successive processing (measured with Sentence Question and Sentence Repetition tasks) and semantics. The RD group was impaired in phonological ability and naming speed, phonological memory, as well as in successive processing. Finally, the SLI group was particularly impaired in naming speed, phonological memory, and semantics. With regard to identification, results indicated a high degree of consistency in the classification scheme. Children from the cormobid group were more likely to be correctly classified (88.9% correct classifications) compared to either the SLI (84.6% correct classifications) or the RD groups (70.0% classifications).

CAS tasks have been also been used alongside other cognitive and linguistic tasks to examine whether theoretical accounts such as those of auditory (e.g., Goswami et al., 2002) and visual (e.g., Stein, Talcott, & Walsh, 2000) processing impairments can be used as alternative explanations of dyslexia in Greek. Specifically, because many of the auditory processing tasks require a lot of attentional resources (Hulslander et al., 2004), Papadopoulos, Georgiou, and Parrila (2012) used the number detection task to control for the effects of attention (along with the effects of verbal and non-verbal ability). Controlling for the effects of these variables was important for the identification of the impact of beat perception deficits in phonological processing and thus reading, as some individual differences in these confounding variables were likely to produce some of the observed discrepancies in the literature with regard to the effects of auditory processing deficits in children with dyslexia or typically developing readers (for a similar discussion see Georgiou, Protopapas, Papadopoulos, Skaloumpakas, & Parrila, 2010). Results indicated that attention and general cognitive ability were indeed among those extraneous variables that are primarily responsible for the rather mixed pattern of beat perception deficits in both groups of children. Thus, the examination of the relationship between beat perception and reading, after implementing controls for these variables, helped to clarify this relationship. Even if such control, particularly for attention, is likely to obscure reverse causation with poor auditory perception causing low attention, it is important to bear in mind that this approach is in direct agreement with the literature demonstrating that the extent to which perceptual organization is influenced by attention is profound (Carlyon & Cusack, 2005) and thus cannot be overlooked.

On the basis of these and other similar findings, Papadopoulos, Georgiou, and Douklias (2009) pilot-tested the hypothesis for a unified theory for dyslexia, exploring longitudinally the convergence among four theories that have been implicated in reading disability: (1) the information processing theory, the Planning, Attention, Simultaneous, and Successive (PASS) theory (assessed with the Cognitive Assessment System, CAS; Naglieri & Das, 1997), (2) the Cerebellar Deficit theory (assessed with the Dyslexia Early Screening Test, DEST-2; Nicolson & Fawcett, 2004), (3) the phonological deficit hypothesis (e.g., Snowling, 2003), and (4) the rapid automatized naming deficit hypothesis (Wolf & Bowers, 1999). Using Structural Equation Modelling and a large cohort of children, results showed that four latent variables, namely, rapid automatized naming, phonological sensitivity, working memory (represented in part by the simultaneous and successive processing subtests from the CAS), and processing capacity (represented by the CAS attention subtests as indicators of controlled processing and the DEST-2 motor tasks as indicators of automated processing), can explain longitudinally individual differences in reading. Thus, the authors proposed that the convergence of cognitive and neuropsychological approaches to understanding dyslexia is possible and that we may be now closer than ever before to the formulation of unified theories.

Given this premise, Papadopoulos and Spanoudis (2011) developed an abbreviated form of the patterns of converging and diverging evidence that can be used in the differential diagnosis of learning disorders, such as reading disabilities, attention deficit hyperactivity disorder, and specific language impairment. Differential diagnosis was possible based on patterns of test results associated with each learning disorder accumulated from a large number of studies carried out in Greek using CAS, alongside other cognitive and linguistic measures. These test results were organized by construct, in order to highlight points of convergence and divergence that would be expected for the profile of a particular disorder. This systematic review located, appraised, and synthesized evidence, helping consider different hypotheses, and provided a rationale for the diagnosis or diagnoses selected.

In sum, from the perspective of the PASS model of cognitive processing, the identification of children with attention and planning deficits, specific learning disabilities (SLD), specific language impairments (SLI), and their possible comorbid deficits helps (a) gain a better understanding of the groups' cognitive profiles and (b) determine the extent to which each of the disorders has its own cognitive subtype or shows some consistent overlap with other similar disorders. At the very least, it is now clear that the difference between the ADD and SLD populations is conceptually related to a specific process deficiency that is well-documented in the relevant literature: children with ADD tend to be deficient in attention and planning, while children with SLD are more likely to be deficient in successive and simultaneous processing. The next section provides further evidence for the validity of this distinction.

## Studies on attention and planning

One of the large scale studies using the CAS in Greek examined the planning performance of children with attention deficits (Papadopoulos et al., 2005). Elementary students with and without teacher-identified attention difficulties were given a variety of executive functioning tasks to measure their planning, flexibility, and anxiety. On a computer-administered planning task, the Crack-the-Code, students with attention difficulties scored worse than the control group; they also spent significantly less time planning what they were going to do to complete the task before they began. The difference in performance between the two groups increased as tasks increased in difficulty. On tasks assessing flexibility, there was no significant difference between the performances of students with attention difficulties and those without. Anxiety was not a factor affecting performance on the executive functioning tasks. The authors concluded that school age children with attention difficulties may require additional help planning how to complete their class assignments because these students do not automatically take time to organize themselves before beginning a task. However, it should not be assumed that students with attention difficulties are less flexible or more anxious than students without attention difficulties when they are completing planning and flexibility tasks.

In the same vein, Papadopoulos and Panayiotou (2007) examined the convergent validity of a screening device for attention deficits in the classroom, namely, the Attention Checklist (ACL; Papadopoulos, Das, Kodero, & Solomon, 2002), assessing in turn the ability of teachers to identify children with attention difficulties. Data were collected among Grade 4 children in Cyprus and Canada. Results showed that in both cultural contexts ACL scores were positively correlated with scores on the cognitive measures of attention from the CAS, indicating, consequently, that teacher ratings using the ACL are sufficiently sensitive in identifying those students who have difficulties with selective attention. Papadopoulos, Giorgatsos, Kritiotou, and Panayiotou (2013) explored this possibility a bit further by examining how well teachers differentiate young learners with attention deficits from those who have also difficulties with behavioural inhibition. In doing so, they tested the factor structure of attention deficits through separate models that were fitted to examine how students' cognitive performance correlates with teachers' ratings in a group of 7-year-olds. Preliminary findings showed that three cognitive factors, as defined by the various cognitive measures used to assess students' performance, were associated with teachers' ratings in identifying those students with attention deficits: attention, working memory (as measured by FM and WS), and planning skills. In turn, speed of processing and behavioral inhibition, along with the above set of skills, were associated with teachers' ratings in identifying those students with the combined subtype of ADHD. These results indicate that the likelihood that attentional skills lie along a continuum that ranges from basic processes, such as behavioral inhibition, to higher order processes, such as planning skills, is high (see also Barkley, 1997, for a similar discussion). Consequently, because attentional abilities can differ among children, even those without ADHD, providing appropriate devices to teachers to assess attention abilities in the classroom is an important function for teachers.

## Implications for intervention

According to J. P. Das (see Molloy and Papadopoulos, 2007 for an exclusive interview) the primary motivation in the development of the CAS was cognitive assessment and *remediation* of cognitive weakness. The first objective was attained by showing that the CAS battery is useful in mapping mental processes. The second objective was largely based on an attempt to develop and test cognitive interventions that could rely on learning styles and teaching strategies. A series of experimental studies in English (e.g., Boden & Kirby, 1995; Carlson & Das, 1997; Das, Mishra, & Pool, 1995; Papadopoulos, Das, Parrila, & Kirby, 2003) attempted to improve academic outcomes through a multidimensional, cognitively focused program, known as PREP (PASS Reading Enhancement Program). PREP was designed to improve selected aspects of children's information processing skills with the ultimate aim being to increase their word reading and decoding abilities (Papadopoulos, 2009; Papadopoulos et al., 2003; Parrila, Das, Kendrick, Papadopoulos, & Kirby, 2000). PREP is an alternative to direct training of strategies for the remediation of cognitive skills supporting subsequent reading skills and is based on the notion that transfer of principles can be facilitated through inductive, rather than deductive, inference. Accordingly, the remedial training is structured in such a way that the inductive inference should occur spontaneously with an internalization of principles and strategies, rather than through deductive rule learning. Remedial training of this kind is more likely to ensure transfer of learned principles and produce strategies for novel situations with higher rates of success (Das et al., 1995; Papadopoulos et al., 2004).

Papadopoulos et al. (2004) examined the effects of PREP on reading ability in Greek with a group of kindergarten children at-risk for reading difficulties which did not differ on verbal and non-verbal ability, age, SES, and gender with a control group of typical readers. The two groups were compared before and after the four-week intervention in Kindergarten, as well as a year after remediation (in Grade 1) on a set of phonological and cognitive (successive and simultaneous processing) measures. As expected, results showed statistically significant effects for all cognitive measures (all *ds* > 1.1), given that PREP involved training in these abilities. However, significant effects were also obtained for phonological awareness, which was not involved directly in the PREP treatment: rhyme oddity ($d$ =1.09), sound isolation ($d$ = 2.29), and phoneme elision ($d$ = 1.47). Interestingly enough, those children whose phonological skills benefited most from PREP had somewhat better initial successive processing and phonological skills.

As a consequence, subsequent research was based on the tradition of aptitude-treatment interaction (Snow, 1989) which is founded on the argument that qualitatively different approaches to reading disabilities cannot be of equal merit. This suggests that for the remedial benefits to be maximized, the cognitive and linguistic processes that may be lacking for learning to read have to be recognized first. As part of a longitudinal experiment, Papadopoulos and Kendeou (2010) examined the direct effects of PREP and of a neuro-psychological program with strong phonological, naming speed, and meaning components (DEST-RT: DEST Remedial Tool) for the remediation of reading difficulties, comparing the two treated experimental groups to a reading-age matched (RA-C), and a chronological age-matched group (CA-C). The results were affirmative, emphasizing the importance of this line of research: if children with specific cognitive strengths and weaknesses are to benefit from a particular intervention program, then identifying their cognitive profiles prior to assigning them to specific remediation programs becomes a necessary prerequisite. Results indicated improvement in all the cognitive, linguistic, reading, and orthographic measures for all four groups as an effect of time. PREP group, however, improved significantly compared to CA-C and DEST-RT in successive processing. Also, PREP outperformed DEST-RT on orthographic choice, an orthographic processing task, tapping the ability to use visual-orthographic information in processing words. Finally, both the PREP and DEST-RT performed significantly better than the CA-C and RA-C in broad and narrow phonological sensitivity, RAN alphanumeric (digit and letter naming), word reading (both real and pseudoword), and passage comprehension. In conclusion, to plan and deliver an intensive reading intervention that is suitable for a child struggling to master reading, it is crucial to have a clear idea of the nature and origins of the child's difficulties (see Papadopoulos, Ktisti, Christoforou, & Loizou, in press, for a thorough discussion).

Ktisti and Papadopoulos (2013) incorporated this approach in a study with a group of 56 Greek-speaking children with reading difficulties (RD), aged 6-7 who were assigned to a 5-week intervention focusing on cognitive (PREP) or phonological (GraphoGame, GG; Saine, Lerkkanen, Ahonen, Tolvanen, & Lyytinen, 2011) training or the two combined (PREP-to-GG or GG-to-PREP). Outcomes were assessed in multiple skills before, during, and after treatment as well as at a follow-up a year later. Repeated measures analyses showed that all groups showed sizable improvements in phonological, naming, cognitive, reading, and spelling skills over time, with significant differences among them in degrees of change. For most RD deficits, children in the PREP treatment showed significantly greater improvement than those given phonological training. Combined treatments did not differ significantly on any direct comparisons, but in some instances (e.g., phonemic decoding) combined PREP-to-GG treatment proved superior to intensive phonological or cognitive training. As a result, the authors supported that for RD intervention, cognitive remediation remains superior to phonological training. In turn, combined treatments did not yield significant greater benefits than cognitive treatment for core RD deficits (such as phonological skills) or for spelling, but provided modest advantages for cognitive skills (such as speech rate) and phonemic decoding.

These results are further supported through microgenetic analysis that explores the learning progress dynamics and the developmental stages of the readers during intervention. Based on the computerized implementation of the above reading intervention programs, Christoforou, Ktisti, and Papadopoulos (2013) recently proposed a novel generic framework for analysing microgenetic data. Using a mathematical methodology that visualized and analysed participants learning progress and the variation in individual gains during intervention, the authors were able to develop a model of *Performance-Effort Space* that captured the learning dynamics of each individual into a common data representation. *Performance* score corresponded to a score of how well a participant executed a particular task and *Effort* score corresponded to the energy (or resources) a participant allocated to the specific task. An example of Performance score could be the number of correct answers during a successful execution of a task. Similarly, an example of an Effort score could be the total exposure time on the task (i.e. total time executing a task, including time for multiple repetitions on the task). The authors concluded that such insights can facilitate the development of adaptive reading intervention programs customized to the progress dynamics of each individual.

In sum, intervention studies show that PASS theory is well-suited to explaining or predicting actual cognitive performance or cognitive change. Its remedial applications provide information on what needs to be changed and how these changes can be induced.

## Future directions and conclusions

The most important question that one may ask is what might be some useful leads for further research. The answer is rather simple: each of the four processes represented in the PASS model requires further investigation to uncover and understand (a) the internal dynamics of these processes, (b) how these processes interact, and (c) how between-subject differences in general cognitive ability might be related to observable differences in the activity of brain systems that support these processes. This new line of research has to be largely based on the use of more advanced methodologies and statistical approaches if our aim is to determine whether human neuroelectrical activity during CAS tasks display similar patterns of individual differences as in the behavioural performance. For instance, the use of EEG (electro-encephalography) methodology is expected to help investigate the psychophysiological basis of the PASS processes, by examining the EEG signals of the brain regions that reflect the cognitive demands of the different CAS tasks. Furthermore, event related potentials (ERPs) can be used to investigate the extent to which groups of different ability, such as dyslexics, may differ from normally reading controls in processing the successive and simultaneous tasks. Likewise, eye movement measures of information processing can also provide additional information about the number and duration of saccades or fixations recorded with an eye-tracker for children with reading deficits, compared to typically developing counterparts. In fact, a project that aims to (a) investigate the cortical dynamics of the component processes involved in reading, orthographic, and information processing for typical and atypical young readers, (b) provide a neurobiological signature for reading failure in Greek, and (c) examine the visual processing and scanning strategies employed by young learners of varying reading and spelling ability, is under development (Fella & Papadopoulos, 2013).

Another promising path for future research concerns the conceptualization of intelligence and its relation to processing speed and efficiency in language representation. The quest for a general measure of intelligence is older than the short history of psychology. A biological trait such as speed of processing information could be a prime candidate. Individuals differ in their speed of processing information and, hence, in their intelligence (e.g., Jensen, 2006). Das, Georgiou, Ciping, and Papadopoulos (2012) have launched a project that examines the universality of speed as an intelligence measure across three different cultures, namely, Canadian, Chinese, and Greek. The pragmatic use of a universal measure of speed is an important concern, especially as it may help to understand reading and language comprehension. Specifically, the present study aims to examine, (a) if speed of processing can be categorized under different types of information, representing major cognitive processes, (b) if processing can be categorized as automatic and intentional, and (c) if the findings on speed of processing generalize across three different languages and cultural groups (English, Greek, and Chinese) to predict word reading and comprehension. With regard to the first question, preliminary findings from structural equation modelling show that the model representing intelligence as a general processing concept rather than processing speed concept is the most parsimonious model with the factor loadings of the obtained constructs being invariant across cultural groups (Papadopoulos, Das, Ciping, & Georgiou, 2013).

Likewise, the examination of the patterns of cognitive abilities that might explain the possible variation between learners in the effectiveness of second language (L2) instructional treatments and the study of differences at individual and group level in implicit, incidental, and explicit L2 learning processes is also a promising path for future research. A major project has been recently launched in Greece aiming to examine the correlations between cognitive variables and outcome measures of second language learning (such as the acquisition of a particular structure or stage of development) in relation to the information-processing demands of different conditions of exposure (Tsimpli, 2013).

Taken together, these new directions pose new challenges to PASS theory. Following a medical and clinical model alongside a psychometric one, future findings are expected to reveal the neuropsychological correlates of PASS processes that will be in line with previous behavioural findings. In addition, by utilizing experimental paradigms that manipulate the PASS processes more directly in different ability and cultural groups, it is expected to further examine structural connectivity and elucidate the nature of these processes.

In conclusion, this paper presents a comprehensive review of the empirical research that has been carried out to date on the PASS neurocognitive theory of intelligence in Greek. It is concluded that when the research is taken as a whole, with regard to the content, quality, and results of the pertinent correlational and intervention studies, the applications of PASS theory in Greek yield similar results to those deriving from other populations who differ in cultural and linguistic characteristics (e.g., Naglieri & Rojahn, 2004; Van Luit, Kroesbergen, & Naglieri, 2005). In short, PASS theory has informed our understanding of human cognition with an emphasis on individuals' strengths and weaknesses. Obviously, this influential theory has the potential to continue to contribute to neurocognitive research in new and exciting directions.

## Endnotes

[1] Barkley reflects the generally accepted suggestion that in the case of children with ADHD, behavioural inhibition appears to be the problem. The fundamental difficulty for children with ADHD is not inattention or poor attention. Rather it is the failure to stop, look, listen, and feel. In other words, a low level of 'behavioural inhibition' is to blame for ADHD syndrome (Das & Papadopoulos, 2003).

[2] Greek standardization: Papadopoulos, Georgiou, & Kendeou (2008)

[3] Greek standardization: Papadopoulos, Georgiou, & Spanoudis (2008)

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