Elsevier Editorial System(tm) for Learning and Individual Differences
Manuscript Draft

Manuscript Number: LEAIND-D-15-00332R3

Title: Mapping and Predicting Literacy and Reasoning Skills from Early to Later Primary School

Article Type: Full Length Article

Keywords: Cognitive development; education; intelligence; mathematics; reading

Corresponding Author: Professor Andreas Demetriou, PhD

Corresponding Author's Institution: University of Nicosia, Cyprus

First Author: Andreas Demetriou, PhD

Order of Authors: Andreas Demetriou, PhD; Christine Merrell, PhD; Peter Tymms, PhD

Abstract: This study explored the relations between early indicators of literacy, numeracy and reasoning with later school performance in these abilities. In pursuit of this aim, appropriate tests were administered to 1073 children at the start of school in England who were divided into four age groups (mean ages of groups: 4.12, 4.37, 4.62, and 4.88 years old) and again during their third year of primary school when they were six to seven years of age. Analysis of variance revealed large improvement in all abilities throughout the fifth year of life. Girls outperformed boys only in language but differences diminished extensively at the end of this year. Structural equation modeling showed that all three abilities of language, mathematics and reasoning emerge as distinct factors strongly related to a general ability factor (G) at both testing waves. General ability at the start of school highly predicted G in the third year of primary school at age 6 - 7 years. The reading ability of children in the second half of the fifth year was also directly related to G at age 6 - 7, especially for girls. Implications for developmental theory and education are discussed.

Cover Letter (confirming paper not published elsewhere)

25 January 2017

Ms. Ref. No.: LEAIND-D-15-00332R2
Title: Mapping and Predicting Literacy and Reasoning Skills from Early to Later Primary School
Learning and Individual Differences

Dear Dr. Grigorenko (Dear Elena):

Thank you for your decision to invite a revision of this paper. Please note that we revised the paper following all of the suggestions of the two reviewers as explained in our response to them. Thus, I hope that you will now be able to accept the paper.

Please note that this paper was not submitted or published elsewhere.

Sincerely yours,

Andreas Demetriou

*Detailed Response to Reviewers

RESPONSE TO REVIEWERS

Reviewer #1: The manuscript improved further compared to its previous draft.

I think that the theoretical framework of the paper could be further strengthened. In the present form of introduction section there is a strong focus on the psychological and psychometric issues, but, as the work is strongly embedded in the educational processes, the paper would benefit from a deeper discussion of the issues of school readiness.

Answer: A paragraph was added in the introduction that connects the study to the school readiness literature. Moreover, relevant comments are inserted in the discussion as well.

The results are presented in details, the correlation tables are informative for the researchers dealing with similar issues, while the SEM analyses summarize well the main relationships.
The correlation tables would be easier to read if the variables would be numbered (a number added before their names), so the correspondence with the numbers in the heading line would be more visible.

Answer: Table 3 and Supplementary Tables corrected as suggested.

Reviewer #2: The authors added an interesting analysis of ability differentiation, largely consistent with previous findings of ability differentiation. They interpret findings separately by test, which is interesting, but it seems hard to know whether these findings generalize to constructs or are test-specific.

Answer: The phenomenon was tested in many other studies now cited in the discussion (p. xx) showing that the differentiation-dedifferentiation cycles are not specific to the measures used here. They are found throughout the period from 4-17 years with many other processes. This provides strong support to the present findings.

I realize that old stage-specific theories of development (or at least commonly asserted versions of them) made the claim that development was discontinuous, but I hardly see it as a novel finding that children improve in their cognitive abilities over the course of a year.

Answer: The reviewer may be right. Educators and parents always knew this. So the statement is scaled: "The present findings call attention to a phenomenon known to all those dealing with learning in children, educators par excellence: They suggest that a year in early childhood is a long time where important changes take place, especially in the case of transition years when mental processes shift from one dominant paradigm of representation to another. Thus, interventions may be more likely to succeed in a particular time window in this short period rather than in another time window." (p.

21).

*Title Page WITH author details

Mapping and Predicting Literacy and Reasoning Skills from Early to Later Primary School

Andreas Demetriou, University of Nicosia, Cyprus

Christine Merrell, University of Durham, UK

Peter Tymms, University of Durham, UK

Address: University of Nicosia Research Foundation, University of Nicosia, Makedonitissas Avenue, P.O. Box 24005, 1700 Nicosia, Cyprus

Email: ademetriou@ucy.ac.cy or demetriou.a@unic.ac.cy

Mapping and Predicting Literacy and Reasoning Skills from Early to Later Primary School

Abstract

This study explored the relations between early indicators of literacy, numeracy and reasoning with later school performance in these abilities. In pursuit of this aim, appropriate tests were administered to 1073 children at the start of school in England who were divided into four age groups (mean ages of groups: 4.12, 4.37, 4.62, and 4.88 years old) and again during their third year of primary school when they were six to seven years of age. Analysis of variance revealed large improvement in all abilities throughout the fifth year of life. Girls outperformed boys only in language but differences diminished extensively at the end of this year. Structural equation modeling showed that all three abilities of language, mathematics and reasoning emerge as distinct factors strongly related to a general ability factor (G) at both testing waves. General ability at the start of school highly predicted G in the third year of primary school at age 6 – 7 years. The reading ability of children in the second half of the fifth year was also directly related to G at age 6 - 7, especially for girls. Implications for developmental theory and education are discussed.

Mapping and Predicting Literacy and Reasoning Skills from Early to Later Primary School

All cognitive functions change extensively in early and middle childhood. From the second year of life onwards, language, mathematical, and reasoning abilities expand and are practiced extensively. From 3 to 5 years children become aware of various aspects of language, including the function of words as representations of objects, actions, and concepts, the phonological organization of sounds in words, and relations between word sounds and writing or pictures (Otto, 2013). In mathematics, children acquire basic arithmetic skills, including the ability to discriminate numerically between sets of objects, operate on small numbers, represent relations between numbers, make judgements about numerical magnitudes, and organize their knowledge in reference to a mental number line (Dehaene, 2011). Also, children at this age demonstrate general inferential and problem solving skills, drawing inductive inferences on the basis of similarities between objects and concepts (Carey, 2009).

At this period of life children often enter formal education. In many countries preschool education starts at 4-5 years and primary school starts at 5-7 years of age (statutorily at 5 in the UK but between age 4 and 5, in practice). Preschool education should emphasize the construction of basic social and cognitive skills that would enable children to adjust to the complex social and symbolic environment of society and prepare them to acquire the reading, arithmetic, and problem solving skills taught in primary school. To be successful, education needs accurate diagnostic tools which specify children’s capabilities in each of the processes mentioned above. The present study was conducted to partly help validate and evaluate one such assessment, the PIPS (Performance Indicators in Primary Schools), on entry to preschool (Tymms 1999, Merrell and Tymms 2001). The PIPS baseline was designed to specify the developmental level of children's abilities at the age of 4 to 5 years. In this study we explore the relationships between three abilities (i.e., language, mathematics, and reasoning) and their predictive power two years later, when children are in their third year of primary school in England (known as Year 2, when children are aged 6 - 7 years). It is noted that PIPS assesses aspects of reading and numeracy that are addressed by many other similar tests (e.g., Cartwright, 2002; van de Rijt et a., 2003). In addition, it involves tests intended to examine abstract reasoning processes. Thus, it can be used to specify both readiness for school-specific processes and also the possible involvement of more general processes that may influence school-related processes.

From an educational perspective, the term "school readiness " refers to the extent to which children have developed skills and abilities that will enable them to succeed in their learning at school (UNICEF, 2012); they are at the stage when they will hopefully learn to read and do simple arithmetic if they are given instruction. It has been the subject of much investigation. For example Duncan et al (2007) showed that early measures of math, reading, and attention were the best predictors of later academic success. Pre-school interventions are often judged initially by their impact on school readiness and some programs have had great success (Ramey and Ramey, 1998). The measurement of school readiness often comes under the heading baseline assessment and a recent publication from UNESCO (2016) gives a flavour of the challenges involved in developing baseline assessments for educational purposes. We hope that this study will provide a refined picture of how mental processes on entrance to school relate to school learning a few years later.

There is a consensus in educational and developmental research literature that these abilities are inter-related and changes in each of them is systematic. There is research showing that early literacy skills, such as letter knowledge, phonological sensitivity, and oral sensitivity are highly stable from 3.5 to 5.5 years (Chistopher, Stephen, & Jason, 2000). Also, counting and relational skills before formal schooling predict the acquisition of basic arithmetical skills and overall mathematical performance in early primary school (Aunio & Niemivirita, 2010). Also, some literacy skills (i.e., print knowledge and vocabulary) but not others (phonological awareness) predict numeracy skills (i.e., numbering, numerical relations, and arithmetic operations) in the 3-5 years period (Purpura, Hume, Sims, & Lonigan, 2011). Evidence about the relations of these skills with broader measures of intelligence is less consistent. On the one hand, there is evidence that general intelligence (Stanovich, Cunningham, & Feeman, 1984) or domain-general abilities such as executive control (Cartwright, 2012) underlie these relations throughout preschool and primary school. On the other hand, some studies found that non-verbal IQ in early preschool does not relate to later reading skills (Cartwright, 2002).

Towards and Integrated Differential-Developmental Model of Learners

To make sense of these findings a comprehensive model is needed that can do justice to both factors underlying individual differences in mental processes and their development with age. Unfortunately, psychometric theories of individual differences of mental abilities underestimate development and developmental theories underestimate factors of individual differences (Demetriou & Spanoudis, 2016). The present study was designed in the context of an integrative model that draws on psychometric and developmental theory.

Specifically, in psychometric theory of individual differences a hierarchical three-level model of the organization of mental abilities is commonly accepted (Carroll, 1993; Deary, 2001; Hunt, 2011). According to this model, individual differences in mental functioning may emerge from any of three independent levels in the organization of mental processes. The first level involves many specific skills, including various reading skills, various mathematical skills, various reasoning skills, etc. These skills are organized into broad abilities at the second level, such as verbal ability, mathematical ability, reasoning ability, etc. For instance, facility in dealing with words, executing arithmetic operations, capturing underlying relations, respectively, may underlie children's ability to learn language, mathematics, or master reasoning processes. These in turn are constrained by very general processes at the first level, such as processing efficiency and inferential power. This is general intelligence or g that is closely reflected in measures of intelligence, such as the IQ, captured by various intelligence tests. For instance, children who are able to keep in mind large amounts of information are more likely than children who are weak in this regard to combine words and decipher their meaning or master the complexities imposed by the abstract nature of mathematical relations. Each higher level is a more powerful source of individual differences because it sets the frame for an increasingly broad set of processes.

However, this model is silent about development, underestimating the role and importance of different mental processes at different phases of development. Demetriou and colleagues (Demetriou et al., 2013, 2014) proposed a developmental model specifying how abilities associated at each of the three hierarchical levels above are expressed and related in development from birth through early adulthood. According to this model, g involves three inter-dependent processes: (i) Abstraction; (ii) representational Alignment; and (iii) Cognizance (hereafter referred to as the AACog mechanism. Abstraction spots or induces similarities between patterns of information, using mechanisms that may vary in development. Alignment is a relational mechanism that maps representations onto each other, enabling comparisons driven by current understanding or learning goals (Demetriou et al., 2013). Cognizance is awareness of the objects of cognition (e.g., “I know that I see a cat), cognitive processes (e.g., “I know that can think of the cat running), allowing executive control and mental planning.

It is beyond the scope of the present paper to discuss the relations between this model and psychometric theory of intelligence (see Demetriou et al., 2014; Demetriou & Spanoudis, 2016) but it is noted here that AACog is only partly related to psychometric g. Like g, it involves abstraction and relational processes allowing search and encoding of similarities or regularities in the environment into representations and concepts. Unlike g, it is minimally inferential and minimally representational. That is, it cannot be identified with any specific type of reasoning, such as inductive and analogical reasoning, or specific aspects of representational efficiency, such as short-term or working memory. Reasoning and problem solving processes in all domains must be constructed as such and representational efficiency processes reflect rather than cause changes in the nature of representations with growth (Demetriou et al., 2013, 2014).

Specifically, it is assumed that this mental core develops in four cycles, with two phases in each. Moving across cycles is associated with the emergence of new forms of representation; changes within cycles are associated with increasing awareness of them and skill in using them. In succession, the four cycles operate with episodic representations from birth to 2 years (remembrances of actions and experiences preserving their spatial and time properties), realistic mental representations from 2 to 6 years (blueprints of episodic representations where spatial and time properties are reduced, associated with symbols, such as words), generic rules organizing representations into conceptual systems from 6 to 11 years, (e.g., concepts about categories of things, exploring causal relations) and overarching principles integrating rules into systems where truth and multiple relations can be evaluated from 11 to 18 years (i.e., principles specifying how rules may be integrated). Changes within cycles occur at 4 years, 8 years, and 14 years, when representations become explicitly cognized so that their relations can be worked out, gradually resulting into representations of the next cycle (Demetriou et al., in press).

Here we focus on the two cycles related to the present study. The first cycle of mental representations lasts from 2 to 6 years. In the first phase of this cycle, from 2 to 4 years, action-based episodic representations of the previous cycle are elevated into symbol-based mental representations. In this early phase, representations have a transparent relation to objects or events and they function as undifferentiated ensembles. Specifically, children use language efficiently in their interactions but they do not yet demonstrate awareness of phonological, grammatical or syntactic characteristics of speech nor do they handle components independently of each other. In mathematics, there are "proto-quantitative schemes" (e.g., "few", "many", "a lot") which are used as representational blocks that may generate mathematical judgments triggered by perceptual appearances. At this phase they can recognize the effect of adding and taking away elements from an aggregation of objects if they lie within the subitization limit (3-4 objects) but they do not yet possess the notions of numerical operations as such. In reasoning, inductive inferences are based on perceptual similarity that enables children to associate objects with categories on the basis of a commonly shared attribute. Language learning draws heavily on this process. For instance, associating an object with a novel name (i.e., “this is a dax” or “this is a diffle”) leads 3-years-old children to infer that other objects of the same shape are “dax” or “diffle” (Becker & Ward, 1991; Landau, Smith, & Jones, 1988). Deductive inference as such does not exist at this phase but representations may be co-activated as components of an experiential block yielding inferences based on the episodic flow of events (e.g., it rains, so we need an umbrella) (Demetriou et al., 2014).

At the age of 4 years children start to be able to focus on the components of representations. For instance, they can map number words or number digits with arrays of up to 6 elements but they do not yet align the two symbol systems with each other. At 5 years they can align all three sets of representations with each other. When this is possible, children start to build concepts in different domains: There must be at least two representations to conceive of a class (e.g. “our cat is an animal”), a quantity (e.g., “Anna has 3 and I have 2; she has more than me”), a cause-effect relation (e.g., “Mary spilled the milk”), a spatial relation, (e.g., “the toy car is “on top of” the book”), or make an inference. Alignment of representational ensembles in this phase optimizes inductive choices and allows deals based on pragmatic reasoning: “We agreed I can play outside if I eat my food; I ate my food; so I go to play outside” (Demetriou, Spanoudis, & Shayer, 2014). This will be raised later into deductive inference.

Early in the next cycle, at 7-8 years there is a shift from “realistic” representations that are visible to the “mind’s eye” to the inferential threads inter-linking them. At the beginning these may function as semantic ensembles defining generic concepts, such as object classes, number, causal attributions, etc. The integration of various conceptual spaces related to number, such as object arrays, number words, counting, digits, etc., into a common mental number line is a good example of an underlying mental construct in the domain of quantitative reasoning (Dehaene, 2011). In the next phase of this cycle, the dimensions or rules defining semantic ensembles can systematically be aligned with each other, yielding hierarchical reasoning about categories and relations. This is also reflected in children’s facility in handling analogies and metaphors (e.g., “teachers are to schools as parents are to families” or the matrices included in the Raven test). Also deductive reasoning involving simple logical schemes such as modus ponens is possible.

The Present Study

The aim of the present study is twofold. On the one hand, it aims to examine the predictive power of PIPS from the age span 4-5 years to the second primary school year at age 6-7. Does PIPS compares well to other similar tests (correlations from .30-.66) (Blatchford et al., 1987; Stuart, 1995) for this early phase of school life? Thus, it is important to also examine its developmental validity. On the other hand, this is an interesting period to study because we have two transitions of different nature. According to the developmental patterns described above, in the 4-5 year period we have the transition from global representations to differentiated representations that may be aligned. The dominant skill at this phase is representational alignment which allows mapping representations onto each other, searching for their similarities and differences and building new representations (metarepresenting) that would integrate the results of this alignment process. At 6-7 years, children shift from the cycle of mental representations to the cycle of rule-based representations. The dominant skill at this phase is inference as such which allows the evaluation and refinement of the relations between representations induced earlier. It is thus interesting to use a very large data base that was created for use in schools to examine several psychometric and developmental hypotheses related to the theory outlined above. The present study will provide a refined picture of how mental processes on entrance to school relate to school learning a few years later. Therefore, this study will shed light on the concept of school readiness from both a differential/developmental and an educational point of view (Duncan et al., 2007; UNESCO, 2016). Our predictions are:

1. In relation to development, there should be systematic improvement of performance on all abilities between age 4 and 5 years of age represented in the first testing wave, reflecting the transition from global representations to representational alignment.

2. In relation to structure, two predictions may be pitted against each other. (i) The first would assume a phase-sensitive structure of cognitive processes. In this case, performance at each testing wave would be represented by a different general factor, each standing for the specificities in organization and interaction between processes that is specific to each phase. In this case, a relation between the two factors lower than unity would be expected. This model would be consistent with the developmental model above assuming that relations between processes are reorganized in different cycles to express differences in representational and processing characteristics. Alternatively, (ii) a common general factor would be sufficient to account for performance at both testing waves. This model would be consistent with psychometric theory which assumes that g stays unchanged in development. Thus, g expresses itself as a common developmental process powerfully orchestrating developmental change and learning over time.

3. According to the developmental model summarized above, each cycle is associated with specific representational characteristics. In the present time span, representational alignment dominates in the 4-6 years phase. Reading is a strong index of this process because it requires mapping multiple systems onto each other, such as sounds to letters or words to writing movements. Inference dominates in the 6-8 years phase. Two major predictions follow from this assumption, one concerning relations between g and specific abilities within each of the two phases and one concerning these relations across phases. With respect to the first, (i) it is expected that the relation between g and specific processes that are central to its operation in

each phase would increase with increasing g. Reading in the first and reasoning in the second phase would strengthen with increasing g to reflect the dominant processes in the formation of the core discussed above. Other abilities that are less central in the formation of g may differentiate with increasing g to indicate that there may be wider variation of performance in more able children as compared to less able children (Molenaar et al., 2010; Spearman, 1927; Tucker-Drop, 2009;). With respect to the second, (ii) it may be expected that reading at first testing would have additional predictive power over g vis-à-vis g at second testing. This would indicate that an advantage in mental processes dominating in the first phase (representational alignment) facilitates transition to rule-based cognition, providing a special developmental advantage to children who are better than other children in this regard. (iii) The psychometric model would not predict any difference between the various processes because these are assumed to be equally related to g.

4. There is literature suggesting that boys and girls develop at different rates, especially in language (Gleason & Ratner, 2008; Hyde, & Linn, 1988). Based on the discussion above, this suggests that girls may have a developmental advantage related to representational alignment. This predicts (i) that girls will outperform boys, especially in reading; (ii) reading in girls may be a stronger predictor of performance at second testing than in boys. However, (iii) no differences are predicted in mathematics or reasoning, as these differences appear latter on in adolescence, if any (Hyde, 2005).

METHOD

Participants

A total of 1073 children were assessed twice. The first testing took place at the start of the first year of school in England, known as the Reception year; this year corresponds to the preparatory preschool year in most other European countries. The second testing took place half way through the third year of school in England, known as Year 2, when the children were aged 6 – 7 years. Age at first testing varied from 4.01 to 5.00 years. There were 610 boys (mean age = 4.53, SD =.28) and 481 girls (mean age = 4.53, SD = .29). The large number of children and their relatively even distribution across the 12 months of the fifth year of life allowed examining the possibility of developmental changes within this year. Thus, for the purposes of some of the analyses to be described below, these children were organized into four age groups. From younger to older, the mean age of the four groups was 4.12 (SD=.07, N = 226), 4.37 (SD = .07, N = 265), 4.62 (SD = .07, N = 287), and 4.88 years (SD = .07, N = 295), respectively.

Schools joined the PIPS project voluntarily and in the majority of cases it was the Local Authority which joined on their behalf and thus all school in the authority joined. Once a school joined, all children starting school were assessed unless they could not communicate well enough to be assessed due to language difficulties or some other special need. Checks of socio-economic status through the home postcode linked to census data indicated the sample was representative of the population of England.

Task Battery and Procedure

The PIPS On-entry Baseline assessment was used. PIPS was created by Peter Tymms in 1994 and then developed with Christine Merrell. It was intended to provide teachers with a profile of their pupils' development within the first few weeks of them starting school for formative purposes and also to provide a reliable and valid measure from which progress could be measured. Details of the sections are presented in Table 1. It can be seen that there were tasks which addressed reading (letter recognition, word recognition, word repetition and word rhyming), arithmetic (counting and addition and subtraction of small (1-3) and larger numbers (4-7), and general problem solving standing for fluid reasoning (draw a person, symbol matching which required to match pictures with symbols or letters, and sequencing of pictures and symbols according to a rule.

PIPS was administered by an adult within the first few weeks of the child starting school (commonly the class teacher) working with one child at a time. The assessment was presented in a manual which contained the instructions and items. There were fourteen sections, each of which consisted of a sequence with stopping rules so that when a child started to make mistakes they moved onto the easiest item in the next section. This provided reliable data and was an enjoyable experience for the child. Cronbach's alpha of this test overall at first testing was high (.84).

The second testing involved tests similar but not identical to the tests included in PIPS. It addressed the following four domains: Reading (word reading and passage reading with multiple choice of words embedded in the text); mathematics (arithmetic, shapes, problems, graphs and tables directly related to the national curriculum of England at the time); vocabulary (picture naming); inductive reasoning (a pattern of dots has to be identified in a larger array based on similarity identification and rule induction). Cronbach's alpha of the tasks overall used at second was also high (.85)

RESULTS

Developmental Patterns and Group Differences

To specify the possible influence of the various factors examined, a 4 (four age groups) x 2 (the two testing waves) x 3 (mean reading, mean mathematics, and mean fluid cognition) repeated measures ANOVA was run (following Bonferoni, significance for $p < .003$; type I SS are used). The main effect of age was highly significant, $F (3, 1004) = 18.428$, $p < .0001$, $\eta_p^2 = .05$, reflecting the fact that performance improved extensively throughout both the 5th and the 7th year of life. The main effect of gender $F (1, 1044) = 2.839$, $p > .09$, and the age x gender interaction, $F (3, 1044) = .835$, $p > .10$, were non-significant. The main effect of wave was not significant, $F (1, 1044) = 1.035$, $p > .10$, due to the nature of z scores (both testing waves have a mean of 0). However, testing wave interacted significantly with gender, $F (1, 1044) = 10.533$, $p < .001$, $\eta_p^2 = .01$, indicating that girls outperformed boys at first wave but their difference was inverted at second wave. Also, the process x gender, $F (2, 1043) = 14.283$, $p < .0001$, $\eta_p^2 = .03$, and the wave x process x gender interaction, $F (2, 1043) = 44.659$, $p < .0001$, $\eta_p^2 = .08$, were highly significant. These interactions indicated that there was a relative superiority of girls at first wave (i) in reading (Cohen's *d* = -.126) and (ii) mathematics (Cohen's *d* = -.132) which, at second wave, increased in reading (Cohen's *d* = -.273) but disappeared in mathematics (Cohen's *d* = -.013); interestingly, an advantage of girls in Gf at first wave (Cohen's *d*= -.265) was inverted at second wave (Cohen's *d*=.243). Therefore, it is clear that genders develop at different rates, with girls maturing earlier and boys catching up later, especially in more general processes. The means and SD of the various measures involved in this analysis are shown in Table 2. The dominant patterns of the various effects are illustrated in Figure 1. It is interesting to study the relations between processes at the various age phases studied here.

Relations between Processes

Structural equation modeling was employed to investigate the structure and the relations between the processes studied here. To attain this aim, several mean scores were created for each process at the two testing waves. For mathematics there were three scores at first testing: counting, adding small numbers, and adding large numbers. For reading, there were scores for writing, ideas about reading, letter recognition, and rhymes. For fluid cognition, there were scores for the draw a person task, induction of relations in a serial pattern, Raven-like figure matching, and picture arrangement. At the second testing, there were four scores: reading, vocabulary, mathematics, and reasoning. The raw correlations between these variables at the level of the total sample are shown in Table 3. The raw correlations according to gender and age are shown in Supplementary Table 1. It can be seen that most of the correlations between these measures were highly significant in all groups.

A first set of models were tested on the whole sample. Two models were pitted against each other, to test the two alternative versions of the second prediction. In line with prediction 2i, in the first model, there was one factor for each of the three sets of scores at first testing (i.e., mathematics, reading, and Gf), a higher-order general factor (G1) related to all three first-order factors at first testing and a common general factor (G2) factor related to all four scores at second testing. In concern to the relations between G1 and G2, there were three versions of this model. The first version assumed no relation between the two factors. The fit of this model was poor, χ^2 (87) = 1531.19, CFI = .79, RMSEA = .121 (CI = .115-.126), model AIC = 1357.19. The second version assumed that the relation between G1 and G2 equals unity. The fit of this model, although better, it was not acceptable, χ^2 (87) = 985.99, CFI = .87, RMSEA = .095 (CI = .090-.101), model AIC = 811.99. In the third version, the relation between the two factors was allowed to vary freely. The fit of this model was significantly better than the second model above ($\Delta\chi^2(1) = 350.12$, $p < .001$) and acceptable, χ^2 (86) = 635.87, CFI = .92, RMSEA = .075 (CI = .069-.080), model AIC = 463.87. It is noted that allowing the error variances of the draw a man test and writing to covary (implying constraints exerted by factors related to using a writing tool), resulted in a large improvement in model fit, χ^2 (85) = 535.01, CFI = .94, RMSEA = .068 (CI = .063-.074), model AIC = 365.01, ($\Delta\chi^2(1) = 100.86$, $p < .001$). This is the model presented in Figure 2. To compare prediction 2i with prediction 2ii, factor G2 was dropped and all four second testing measures were regressed on G1, which is thereby rendered common to the two testing waves. The fit of this model was much weaker than the fit of the fourth model above, χ^2 (86) = 758.80, CFI = .83, RMSEA = .083 (CI = .077-.088), model AIC = 586.80.

Therefore, it is clear that prediction 2i dominated over prediction 2ii, implying that specificities in the organization of cognitive processes in different phases of development and learning may alter the organization of mental processes. It is noted that all factors were clearly identified, as all relations between all first wave factors to G1 (all > .9) and all second wave factors to G2 (all > .65) were very high. We take this factor to stand for the AACog core outlined in the introduction. The G1-G2 relation was also very high (.86). It is noted that this relation reflected the fact that G1 exerted significant and high indirect effects on all four second wave measures (.72, .74, .62, and .55 for arithmetic, reading, vocabulary, and Gf, respectively). In concern to prediction 3, in this model, it was meaningless to test if there was any additional impact of first testing reading on second testing G2 because the variance of reading was fully absorbed by G1.

To test if these relations vary as a function of age, the best fitting model was tested in a two-group analysis in which the two younger age groups described in method formed one group and the two older age groups formed another group. This model was first tested under the strict constraint that all indicator-factor relations and all factor-factor relations were equal across the two groups. These constraints implement the assumption that all measures were equally good indexes of the latent factors in the two groups and that these groups are structurally identical. The fit of this model was acceptable, χ^2 (180) = 603.14, CFI = .93, RMSEA = .066 (CI = .060-.071), model AIC = 243.14. To test if structural relations may vary between groups, the constraint that the relations between G1 and G2 would be equal between groups were released. Also, to examine the third prediction above, the G2 factor in the older age group was regressed on both the residual of the first testing reading and the mathematics factor, in addition to G1. This was not possible in the younger age group because there was no residual variance left for these factors. The fit of this model was significantly better than the model above, χ^2 (177) = 592.08, CFI = .94, RMSEA = .065 (CI = .060-.071), model AIC = 238.08, ($\Delta\chi^2(3) = 11.06$, $p < .025$). In this model, the G1-G2 relation in the younger group was very high (.84). In the older age group, this relation was also very high (.80). In addition, however, the relation between the first wave residual reading factor and G2 was significant and high (.60); the relation between G2 and the residual mathematics factor was non-significant (.18) (see Figure 2).

Differences between Genders

To examine possible differences between the genders, the model shown in Figure 2 was tested separately on the two genders, under the assumption that the measurement-factors relations were equal across the two genders but the factor-factor relations may vary. In this model, the G2 factor was regressed on both the G1 and the residual first testing reading factor.

The fit of the model was also good, χ^2 (178) = 613.01, CFI = .94, RMSEA = .066 (CI = .060-.071, model AIC = 257.01). The G1-G2 relation was high in both genders (.84 and .81 for boys and girls, respectively). The G2-reading relation was appreciable in both boys (.54, z = 1.50, p > .05) and girls (.58, z = 2.32, p < .001) but it was significant only for girls (see Figure 2). These findings are in line with prediction 4(ii).

Differentiation with Ability and Growth

To specify the possible differentiation of processes as a result of increasing ability or age a model recently proposed by Tucker-Drob (2009) was employed. This is a structural equation model which allows a test of the possible differentiation of abilities with increasing g and/or development. This model specifies how abilities relate to g, age, a factor standing for possible differentiation of abilities from g according to increasing g, and a factor standing for a possible differentiation of abilities as a function of age. Technically, a standardized measure of each ability is regressed on a common factor standing for g, on age, on quadratic g, and on the age x g product to stand for the relations specified above, respectively. This model was tested on the whole sample separately on each of the two testing waves. For the first wave, there were four mean z scores: reading (letters and word), phonological ability (rhymes and repeats), mathematics (mean of all three scores addressed to numbers), and reasoning (mean of sequence, pictures and draw a man). All four scores available at the second wave were used (mathematics, reading, vocabulary, and reasoning. The model was tested separately on each wave rather than in a single model that would include both waves because, first, this would highlight any possible differences between the two developmental phases represented by the two waves. Additionally, the models already presented above suggested that assuming a separate general factor for each wave is preferable over assuming one factor.

The models for each wave were tested in a stepwise fashion. That is, at a first run, the four ability-specific indexes above were regressed only on g (AIC = 9912 and 11252, for the two waves, respectively). The second run included g and age (AIC = 9494 and 10829). The third run involved two alternative models: (i) in the first, the ability differentiation quadratic g index was also included in each equation (AIC = 8665 and 10754); (ii) in the second, quadratic g was dropped and age differentiation (g x age) factor was used (AIC = 9911 and 11834). Finally, all indexes were included in the model (AIC = 8651 and 10756).

Step-wise comparisons of the successive models in each age group (see AIC indexes above) suggest that adding the ability differentiation factor in the model including g and age resulted in a large improvement of the model fit in both waves. The fit of the model including both differentiation factors was either basically the same or slightly weaker than the fit of the model including ability differentiation only. Therefore, at a global level, the data supported the operation of ability differentiation but not age differentiation which appeared redundant to ability differentiation.

[Insert Table 4 about here]

The results of the two full models are summarized in Table 4. "It is important to inspect the direction and statistical significance of each of the terms in order to evaluate whether the ability differentiation and age differentiation hypotheses were supported. To accept such support, the parameters should be in directions indicative of lower loadings at high ability levels, [and] lower loadings with increasing childhood age …. Moreover, the effects should not be isolated to a single broad ability, but should instead be statistically significant and consistent in direction for multiple abilities.” (Tucker-Drob, 2009, p. 17). In other words, significant negative relations between the differentiation constructs and specific abilities would indicate differentiation. Significant positive relations would imply de-differentiation or tightening of relations between g and specific abilities with increasing g. Non-significant relations would imply that differences in are not connected to any specific pattern in a given ability.

Inspection of Table 4 suggests that there are both similarities and differences between the two testing waves, such that the overall pattern is consistent with prediction 3i. It can be seen that there is differentiation at both waves in some abilities. Specifically, (mathematics= -.112 and -.165, $p < .0001$ for both, respectively), phonics, (-.218, $p < .0001$) and reasoning (-.141, $p < .001$) appear differentiated with increasing g at first wave; mathematics (-.159, $p < .0001$) and reading (-.08, $p < .05$) did but vocabulary (-.05, $p > .10$) did not differentiate with g at second wave. As expected, however, reading was found to de-differentiate with both g (.375, $p < .0001$) and age (.241, $p < .02$), at first wave; reasoning de-differentiated at second wave (.11, $p < .005$). In other words, some abilities within each phase increase with g reflecting the cognitive priorities of the phase concerned. In the 4-5 years phase, learning reading is a process reflecting representational alignment par excellence. It was precisely this ability that was found to augment with increasing g. In the 7th year of life, g is primarily specified by rule-based inference. Hence, it was in this phase that reasoning appeared to augment with g. Abilities that are not directly tight to these priorities may differentiate with increasing g to reflect differences between individuals in learning priorities or opportunities. The implications of these findings will be discussed below.

DISCUSSION

The present findings suggest useful theoretical implications for developmental and psychometric theory and practical implications for education and clinical practice. These are discussed below.

Implications for developmental theory. It is recalled that, in line with the first prediction, there were systematic changes throughout the fifth year of life in all of the processes addressed (Figure 1). In line with developmental theory, these changes indicate that during this year children start to access their mental representations as such, scan their components, and inter-related them. This process is highly important especially in concern to reading and writing because these processes require mapping representations onto each other and integrating them into smoothly running complex skills.

In developmental theory, a year of age is often taken as a single point that is compared to the preceding and following years. In fact, in stage theories of cognitive development (Piaget, 1970; Case, 1985; Fischer, 1980; Halford, Wilson, & Phillips, 1998) periods longer than a year are taken as envelopes which are characterized by a particular cognitive profile that is considered to be more or less stable within the age limits concerned. The present findings call attention to a phenomenon known to all those dealing with learning in children, educators par excellence: They suggest that a year in early childhood is a long time where important changes take place, especially in the case of transition years when mental processes shift from one dominant paradigm of representation to another. Thus, interventions may be more likely to succeed in a particular time window in this short period rather than in another time window. This is further discussed below. It is also notable that ability in the fifth year of life was strongly predictive of attainment two years later, in the second primary school year. Obviously, the new mental structure formed at 6-7 years emerges from these constructions at 4-5 years (prediction 2i). It is also to be stressed that, in line with the third prediction, reading skills in the second half of age 4 bear extra predictive power, indexing the alignment processes that dominate in this developmental phase. Therefore, the present findings call attention to processes that may be more indicative of children's school readiness rather than other measures (Duncan et al., 2007; UNESCO, 2016).

Implications for psychometric theory. There is a long debate in psychometric theory about the relations between g and specific processes at different levels of g (e.g., different IQ levels). Spearman (1927) suggested that abilities differentiate from each other with increasing g because higher ability allows more flexible learning in different domains causing abilities to depart from each other. The developmental adaptation of Spearman's differentiation hypothesis assumes that abilities differentiate with growth because of development in g. Although earlier research provided some support to this hypothesis (Deary et al., 1996; Detterman & Daniels, 1989), recent research employing stricter modeling methods provided rather weak and inconsistent evidence in favor of ability differentiation and no evidence for age differentiation (Molenaar et al., 2010; Tucker-Drop, 2009). The findings offer a reason for this state of affairs. Both differentiation and de-differentiation of specific mental processes vis-à-vis g may happen but they are phase-specific and ability-specific. It is noted that these differentiation-de-differentiation patterns are not specific to this study. Several recent studies showed that similar patterns were found across all developmental cycles from 4 through 17 years of age: At the beginning of each cycle relations of g with processes that initiated the cycle but they then automate, such as attention control, become loose; relations of g with processes that consolidate the cycle, such as processes driving inference and awareness about it, get strengthened (Demetriou, Spanoudis, Kazali, Mouyi, & Zebec, submitted; Makris, Tachmatzidis, Demetriou, and Spanoudis, in press).

Naturally, highly able children have more cognitive capital to invest in their interests or match with environmental opportunities resulting with high performance in one domain and lower in another domain. Less able children tend to perform more uniformly across domains. Therefore, the present study contributes to the integration of developmental and psychometric theory because it shows how powerful developmental processes may contribute to the nature and timing of individual differences in mental functioning and learning. In fact, in line with the fourth prediction, differences in the rate of development of these skills in different groups of the population are predictive of broad group differences, such as gender differences.

Educational and clinical implications. The findings are relevant for both assessment and intervention in schools. Cognitive tests must be refined enough to capture the particular events occurring in each successive micro-period of development that may span over several weeks or months of life, because these may be important for later achievements. Also, valid tests must address both domain general and domain-specific processes to specify the child’s specific state of command of each of them. In concern to domain-general processes, diagnosis would have to focus on the child’s resolution of awareness of processes and its executive ability to work on them in order to compare, differentiate, or integrate them. For domain-specific processes, diagnosis would have to focus on the command of specific skills of interest that are needed to meet specific learning tasks, such as reading, writing, and dealing with numbers. The present findings suggest that lags at any level may be the source of level-specific problems. On the one hand, weakness in central awareness and executive may hinder the integration of lower level skills that may be available, such as letter recognition, script skills, counting and enumeration skills etc. On the other hand, weakness in specific skills such as those mentioned here may leave otherwise efficient central abilities devoid of the content that is necessary for them to function and open transition to a next level of development or learning. This study showed that the PIPS baseline generates information relating to key features of children's developing domain-general and domain-specific profiles which are predictive of later performance in reading, mathematics, and vocabulary, and problem solving.

It is also notable that predictive power varies as a function of an interaction between age, ability, and gender. Specifically, on the one hand, all subtests are very strong predictors because they are all derivatives of a strong general mental ability construct. On the other hand, the predictive power of each varies in development, depending upon its developmentally sensitive contribution to the formation of general inferential processes. Specifically, reading provides extra predictive power at age 4, although this is higher if made from the second rather than the first half of the fifth year; for girls it may take place even from the first half, reflecting their relatively earlier language proficiency. Mathematics in this age period does not provide any extra predictive power because it is fully absorbed by the mental common core. This study suggests that PIPS may be used early when children enter preschool to spot children who are in need for special support to master school related skills, such as reading and mathematics.

These findings suggest that interventions may be more likely to succeed in a particular time window rather than in another time window. Moreover, to succeed, interventions need to focus on the specific abilities that are under formation in this particular time window. Specifically, it is suggested that it might be very useful to develop special intervention programs and guidance for teachers addressed to the alignment processes underlying learning priorities at the start of school. Special training programs to facilitate children's awareness of their representations, mentally focus on them, analyze their components, and relate them to symbols, such as writing, script, and other pictorial material, may enhance their learning of school-relevant concepts and skills, such as number, reading, and writing (Demetriou, 2014; Demetriou et al., 2011). Research suggests that involving preschool children in programs specifically designed to strengthen these skills in preschool significantly benefits their learning in primary school (Howes et al, 2008). In early primary school, emphasis must shift to underlying relations and their encoding into usable rules. That is, children must refine their understanding of the process- and rule-specific constrains of relations between representations.

Further, this test may be used as a preliminary tool for identifying children in need of further, more focused, diagnosis for possible problems in more central processes, such as executive control and working memory. That is, children performing low on PIPS may be referred to for testing by tests specifically addressed to executive control and working memory. These problems are often associated with more severe learning difficulties, such as the attention deficit and hyperactivity disorder. It is well established that early diagnosis and treatment of these problems reduces the risks for both learning and adaptation problems to the school environment (Diamond, 2013; Dougherty et al, 2015; Jogi & Kikas, 2015). The time is ripe to take the new understandings forward and to bring them to the attention of teachers, teacher educators and policy makers so that a new approach which integrates all of our insights can be taken forward.

One might suggest that this study is limited in several respects. Specifically, it addressed processes relevant to one particular educational system, England, and one language, English. Also, it addressed only some of the educationally relevant processes, related to literacy and numeracy, ignoring others, such as executive and working memory processes. Obviously, this study presents an assessment that would have to be adjusted to other educational systems by drawing on relevant material and educational aims and paired to tests addressing other cognitive and probably social processes and skills.

References

Aunio, P., & Niemivirita, M. (2010). Predicting children's mathematical performance in grade one by early numeracy. *Learning and Individual Differences, 20,* 427-435.

Becker, A. H., & Ward, T. B. (1991). Children's use of shape in extending novel labels to animate objects: Identity versus postural change. Cognitive Development, 6, 3-16.

Blatchford, P., Burke, J., Farquhar, C., Plewis, I. & Tizard, B. (1987). Associations between pre-school reading and related skills and later reading achievement. *British Educational Research Journal, 13,* 15-23.

Brock, Rimm-Kaufman, Nathanson, & Grimm (2009). The contributions of 'hot' and 'cool' executive function to children's academic achievement, learning-related behaviors, and engagement in kindergarten. *Early Childhood Research Quarterly, 24,* 337–349.

Carey, S. (2009). *The origins of concepts*. Oxford: Oxford University Press.

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. New York: Cambridge University Press.

Cartwright, K. B. (2002). Cognitive development and reading: The relation of reading-specific multiple classification skill to reading comprehension in elementary school children. *Journal of Educational Psychology, 94,* 56–63.

Cartwright, K. B. (2012) Insights From Cognitive Neuroscience: The importance of executive function for early reading development and education. *Early Education and Development, 23,* 24-36, DOI: 10.1080/10409289.2011.615025

Case, R. (1985). *Intellectual development: Birth to adulthood*. New York: Academic Press.

Case, R., Demetriou, A., Platsidou, M., Kazi, S. (2001). Integrating concepts and tests of intelligence from the differential and developmental traditions. *Intelligence, 29,* 307-336.

Christoforides, M., Spanoudis, G., & Demetriou, A. (in press). Coping with logical fallacies: A developmental training program for learning to reason. *Child Development.*

Chistopher, L. J.; Stephen, B. R., & Jason, A. L. (2000). Development of emergent literacy and early reading skills in preschool children: Evidence from a latent-variable longitudinal study. *Developmental Psychology, 36*, 596-613. doi.org/10.1037/0012-1649.36.5.596

Deary, I. J. (2000). *Looking down on human intelligence.* Oxford: Oxford University Press.

Dehaene, S. (2011). *The number sense: How the mind creates mathematics.* Oxford: Oxford University Press.

Deary, I. J., Egan, V,, Gibson, G. J., Brand, C. R., Austin, E., & Kellaghan, T. (1996). Intelligence and the differentiation hypothesis. *Intelligence, 23,* 105‑132.

Demetriou, a. (2014). Learning to learn, know, and reason. In R. Deakin Crick, C. Strinher, & K. Ren (Eds.), *Learning to learn: International perspectives from theory and practice* (pp. 41-65). London: Routledge.

Demetriou,A., Spanoudis, G., Kazali, E., Mouyi, A., & Zebec, M. (Submitted). Differentiation and de-differentiation of mental processes from g as a function of developmental phase.

Demetriou, A., Spanoudis, G., & Mouyi, A. (2011). Educating the developing mind: Towards an overarching paradigm. *Educational Psychology Review, 23,* 601-663.

Demetriou, A., Spanoudis, G., & Shayer, M. (2014). Inference, reconceptualization, insight, and efficiency along intellectual growth: A general theory. Enfance, Vol. 2014, 365-396, DOI: 10.4074/S0013754514003097.

Demetriou, A., Spanoudis, G., Shayer, M., Mouyi, A., Kazi, S., & Platsidou, M. (2013). Cycles in speed-working memory-G relations: Towards a developmental-differential theory of mind. *Intelligence, 41*, 34–50.

Demetriou, A., Spanoudis, G., Shayer, M., van der Ven, S., Brydges, C., R., Kroesbergen, E., Podjarny, G., Swanson, L. H. (2014). Relations between speed, working memory, and intelligence from preschool to adulthood: Structural equation modeling of 14 studies. *Intelligence, 46*, 107-121.

Detterman, D. K., & Daniel M. H. (1989). Correlations of mental tests with each other and with cognitive variables are highest for low-IQ groups. *Intelligence 13*, 349‑359.

Diamond, A. (2013). Executive Functions. *Annual Review of Psychology, 64*, 135-168.

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., ... & Sexton, H. (2007). School readiness and later achievement. *Developmental psychology*, *43*, 1428.

Fischer, K. W. (1980). A theory of cognitive development: The control and construction of hierarchies of skills. *Psychological Review, 87*, 477–531.

Gleason, J. B., & Ratner, N. B. (2008). *The development of language*. New York: Pearson.

Greiff, S. Wusterberg, S., Csapo, B., Demetriou, A., Hautamaki, J., Graesser, A., & Martin, R. (2014). Domain-general problem solving skills and education in the 21st century. *Educational Research Review, 13,* 74-83.

Halford, G. S., Wilson, W. H., & Phillips, S. (1998). Processing capacity defined by relational complexity: Implications for comparative, developmental, and cognitive psychology. *The Behavioral and Brain Sciences*, *21*, 803–864.

Howes, C., Burchinal, M., Pianta, R., Bryant, D., Early, D., Clifford, R., Barbarin, O. (2008).

Ready to learn? Children's pre-academic achievement in pre-Kindergarten programs. *Early Childhood Research Quarterly, 23*, 27–50.

Hyde, J. S. (2005). The gender similarity hypothesis. *American Psychologist, 60,* 581–592

Hyde, J. S., & Linn, M. C. (1988). Gender differences in verbal ability: A meta-analysis. *Psychological Bulletin, 104,* 53– 69.

Jensen, A. R. (1998). *The* g *factor: The science of mental ability*. Westport, CT: Praeger.

Jogi, A.-L. & Kikas, E. (2015). Calculation and word problem-solving skills in primary grades – Impact of cognitive abilities and longitudinal interrelations with task-persistent behavior. *British Journal of Educational Psychology*, *85,* 1-17.

Landau, B., Smith, L. B., & Jones, S. S. (1988). The importance of shape in early lexical learning. *Cognitive Development, 3*, 299-321.

Dougherty, L. R. Leppert, K. A., Bufferd, S. J., Merwin, S. M., Kushner, M. R., & Smith, V. C. (2015). Advances and Directions in Preschool Mental Health Research. *Child Development Perspectives, 9*, 14-19.

Lautrey, J. (2002). Is there a general factor of cognitive development? R. J Sternberg & El. L. Grigorenko (Eds.), *The general factor of intelligence: How general is it?* (pp. 117-148). Mahwah, NJ: Lawrence Erlbaum.

Makris, N., Tachmatzidis, D., Demetriou, A., & Spanoudis, G. (in press). Mapping the evolving core of intelligence: Changing relations between executive control, reasoning, language, and awareness. *Intelligence*, 10.1016/j.intell.2017.01.006

McClelland, M. M., Cameron, C. E., Connor, C. M. Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. *Developmental Psychology, 43,* 947-959.

Merrell, C., & Tymms, P. B. (2001). Inattention, hyperactivity and impulsiveness: Their impact on academic achievement and progress. *British Journal of Educational Psychology, 71*, 43-56.

Molenaar, D., Dolan, C. V., Wicherts, J. M., van der Maas, H. L. J. (2010). Modeling differentiation of cognitive abilities within the higher-order factor model using moderated factor analysis. *Intelligence, 38*, 611-624

OECD (2012a). *Better skills, better jobs, better lives. A strategic approach to skills policies*. Paris: OECD.

OECD (2012b). *PISA 2015 Collaborative Problem Solving assessment framework.* Presented at the 33rd meeting of the PISA Governing Board. Tallinn, OECD.

Otto, B. W. (2013). *Language development in early childhood education*. New York: Pearson.

Piaget, J. (1970). Piaget's theory. In P. H. Mussen, (Ed.), *Carmichael's handbook of child development* (pp. 703-732). New York: Wiley.

Purpura, D. J., Hume, L. E., Sims, D. M., & Lonigan, C. J. (2011). Early literacy and early numeracy: The value of including early literacy skills in the prediction of numeracy development. *Journal of Experimental Child Psychology, 110*, 647-658.

Ramey, C. T., & Ramey, S. L. (1998). Early Intervention and Early Experience. *American Psychologist, 53*, 109-120.

Stanovich, K. E., Cunningham, A. E., & Feeman, D. J. (1984). Intelligence, cognitive skills, and early reading progress. *Reading Research Quarterly, 19,* 278-303.

Stuart, M. (1995). Prediction and qualitative assessment of 5- and 6-year-old children's reading: a longitudinal study. *British Journal of Educational Psychology, 65,* 287-296.

Tucker-Drob, E. M. (2009). Differentiation of cognitive abilities across the lifespan.

Developmental Psychology, 45, 1097-1118.

Tymms, P.B. (1999). *Baseline assessment and monitoring in primary schools: achievements, attitudes and value-added indicators*. London: David Fulton Publishers.

Tymms, P., Merrell, C., & Henderson, B. (1997). The First Year at School: A quantitative investigation of the attainment and progress of pupils. *Educational Research and Evaluation, 3*(2), 101-118.

UNESCO. (2016). *Understanding what works in oral reading assessment* doi:10.15220/978-92-9789-196-2-en

UNICEF (2012). School Readiness: A Conceptual Framework. Unicef: New York.

van de Rijt, B., Godfrey, R., Aubrey, C., van Luit, J. E. H., Ghesquiere, P., Torbeyns, J., Haseman, K., Tancig, S., Kavkler, M., Magajna, L., & Tzouriadou, M. (2003). The development of early numeracy in Europe. *Journal of Early Childhood Research, 1,* 155-180.

Table 1. Description of tasks in the PIPS Assessment

Name of Section	**Description**	**Number of Items & Scoring**
Draw A Person	Children asked to draw a person and this was rated on a five-point scale.	1 item Score of 1 – 5
Writing	Children asked to write full name and the quality was rated on a five-point scale.	1 item Score of 1 – 5
Pictures	Children shown a page with nine pictures. They were asked to point to items such as a crocodile.	9 item Each scored one mark
Matching	Children shown symbols or letters and asked to find matching image from a choice of three options.	16 items Each scored one mark
Ideas about Reading	Children shown a picture scene and asked to distinguish between people who are reading and writing, and identify features of writing such as pointing to a word and a letter of the alphabet	6 items Each scored one mark
Letters	Administrator pointed to a letter of the alphabet and asked the children if they could say what it was. A mixture of upper and lower case letters covering all letters of the alphabet were included in section. Letter sound or name was accepted as correct.	26 items Each scored one mark
Words	Administrator pointed to a word and asked	9 items

	children to read it aloud.	Each scored one mark
Rhymes	Children listened to a series of three words said by the administrator at the same time as looking at pictures of the words. Children were asked to say which word rhymed with the first word. E.g. 'Mouse, House, Moon'.	6 items Each scored one mark
Repeats	Administrator said a nonsense or unfamiliar word and children were asked to repeat each word.	8 items Each scored one mark
Count	Children were asked to count a number of objects up to a maximum of 25.	Score 0 – 25
Sums A	Addition and subtraction items. E.g. Children shown picture of two cats and administrator said: 'Here are two cats. If one more was added to the picture, how many would there be?'	6 items Each scored one mark
Sequences	Sequences of pictures and symbols	7 items Each scored one mark
Numbers	Single and double digits were shown to the children. Administrator asked 'Do you know what this number is?'	15 items Each scored one mark
Sums B	More advanced arithmetic (e.g., 2 + 2 =)	4 items Each scored one mark

Note: For more information about the PIPS Baseline assessment, see Tymms, Merrell and Henderson (1997). Tymms (1999) and www.ipips.org

Table 2. Mean z scores and SD across age, gender, testing wave and ability

Age	Sex		Reading 1	Maths 1	Gf 1	Reading 2	Maths 2	Gf 2
4-3	Boy	Mean	-.179	-.227	-.276	-.235	-.217	-.217
		SD	1.121	1.007	.753	1.011	1.083	1.083
	Girl	Mean	-.187	-.270	-.156	-.158	-.303	-.303
		SD	.904	.946	.719	.935	.956	.956
4-6	Boy	Mean	-.178	-.239	-.171	-.378	-.148	-.148
		SD	1.009	.933	.678	1.016	1.024	1.024
	Girl	Mean	.0110	-.111	.088	.055	-.031	-.031
		SD	.960	.943	.682	.927	.938	.938
4-9	Boy	Mean	-.045	-.022	-.061	-.156	.132	.133
		SD	.966	.919	.666	1.030	.980	.980
	Girl	Mean	.139	.203	.157	.259	.236	.236
		SD	.924	.876	.667	.926	.956	.956
5-0	Boy	Mean	.206	.231	.151	.159	.340	.340
		SD	1.013	1.120	.7836	1.006	1.022	1.022
	Girl	Mean	.292	.360	.348	.276	.302	.302
		SD	.984	.989	.807	.841	.903	.903

Age specified in years-months.

Table 3. Correlations between the variables used in structural equation modeling (total sample, N=1073).

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Draw per	1.000														
2. Pictures	.295	1.000													
3. Sequences	.264	.347	1.000												
4. Matching	.365	.370	.359	1.000											
5. Counting	.326	.318	.402	.409	1.000										
6. Sums A	.338	.352	.455	.415	.508	1.000									
7. Sums B	.091	.071	.148	.147	.149	.217	1.000								
8. Writing	.544	.319	.320	.448	.448	.435	.195	1.000							
9. Ideas Read	.269	.457	.312	.394	.250	.329	.073	.322	1.000						
10. Letters	.351	.269	.345	.450	.522	.458	.251	.543	.261	1.000					
11. Phonics	.352	.428	.426	.449	.438	.437	.165	.419	.390	.422	1.000				
12. Y2 math	.371	.345	.320	.453	.468	.472	.177	.481	.362	.498	.443	1.000			
13. Y2 read	.430	.367	.343	.455	.480	.476	.177	.536	.351	.590	.480	.734	1.000		
14. Y2 vocab	.304	.470	.320	.374	.376	.419	.130	.403	.396	.493	.470	.587	.606	1.000	
15. Y2 reason	.296	.261	.314	.379	.390	.390	.151	.376	.245	.370	.365	.572	.531	.467	1.000
Mean z	.020	.002	.007	.004	-.001	.002	-.000	.015	.011	.014	-.001	.059	-.023	-.169	.056
SD	1.012	1.023	.995	.995	.996	1.002	.996	1.006	.992	1.002	1.000	1.011	.993	1.094	.9734

R = .074, p < .01; R = .144, p <.0001.

Table 4. Full model testing ability and age differentiation across testing waves on total sample

Ability	g	age	g^2	Age x g
Wave 1				
Arithmetic	**.817**	**.677**	**-.117 (-.175-.060)**	-.021 (-.292-.250)
Reading	**.784**	**.277**	**.390 (.319-.461)**	**.241 (-.015-.498)**
Phonics	**.678**	**.503**	**-.226 (-.294--.158)**	-.186 (-.481-.110)
Reasoning	**.566**	**.547**	**-.146 (-.194-.098)**	-.039 (-.261-.183)
Wave 2				
Arithmetic	**.863**	**.785**	**-.159 (-.214--.105)**	-.106 (-.305-.093)
Reading	**.802**	**.567**	-.081 (-.183-.021)	-.033 (-.285-.218)
Vocabulary	**.798**	*.212*	**-.053 (-.147-.041)**	.008 (-.259-.276)
Reasoning	**.683**	**.444**	**.111 (.009-.214)**	.025 (-.267-.317)

Note: Numbers are estimates in all cases but the standardized relations in the linear model.

(99% confidence intervals in parenthesis). Significance: **Bold: p < .05;** *Italics: p <.10.*

A. Reading B. Mathematics C. Fluid intelligence

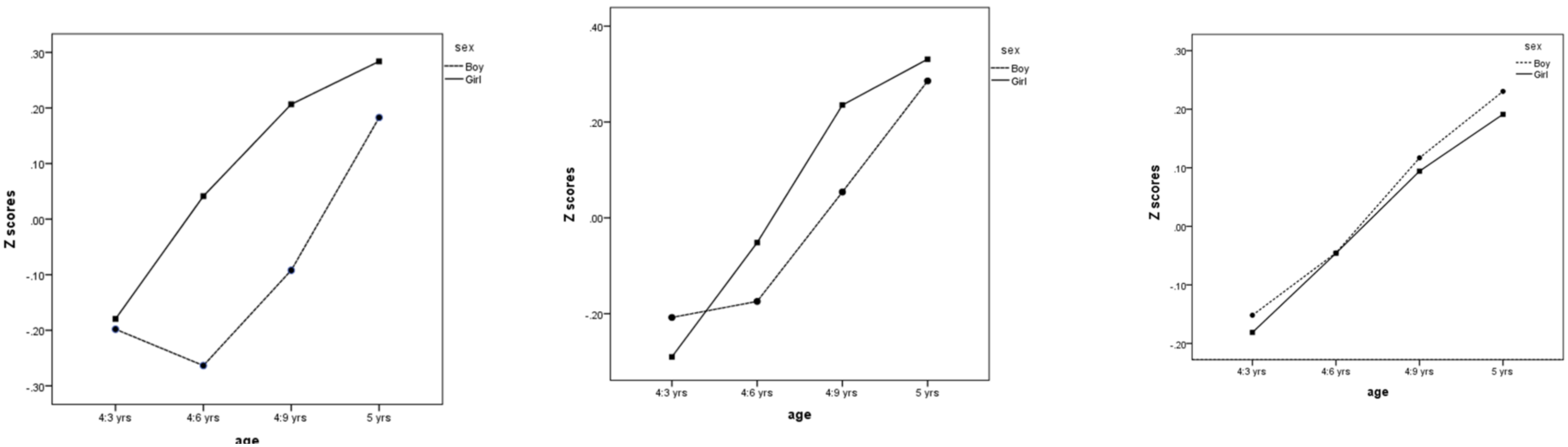

Figure 1. Performance at first wave as a function of age group, ability, and gender.

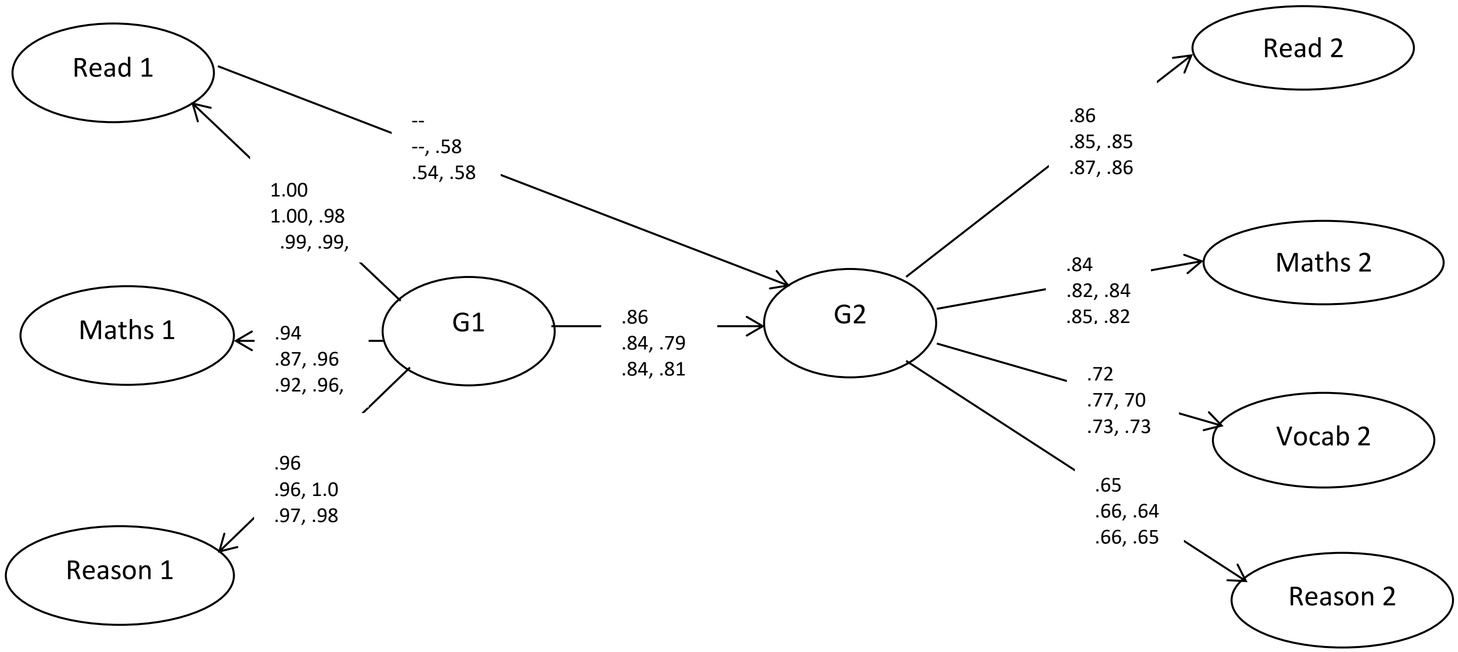

Figure 2. Structural equation models of the relations between abilities.

Note: The first raw in each set come from the model applied on the whole sample, the second raw comes from the model applied on the two age groups (younger, older), and the third comes from the model applied on genders (boys, girls).

Table

Supplementary Table 1A. Correlations between the variables used in structural equation modeling (girls, N=481).

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Draw per	1.000														
2. Pictures	.311	1.000													
3. Sequences	.253	.291	1.000												
4. Matching	.358	.353	.384	1.000											
5. Counting	.318	.324	.376	.441	1.000										
6. Sums A	.326	.325	.396	.388	.457	1.000									
7. Sums B	.057	.064	.122	.102	.107	.169	1.000								
8. Writing	.541	.285	.266	.443	.427	.409	.178	1.000							
9. Ideas Read	.229	.370	.269	.368	.220	.257	.051	.293	1.000						
10. Letters	.390	.275	.341	.481	.486	.420	.194	.528	.248	1.000					
11. Phonics	.377	.395	.382	.458	.442	.434	.149	.387	.340	.410	1.000				
12. Y2 Math	.373	.284	.311	.470	.445	.411	.144	.491	.300	.473	.411	1.000			
13. Y2 Read	.411	.365	.323	.449	.437	.427	.123	.530	.321	.577	.446	.727	1.000		
14. Y2 vocab	.340	.467	.326	.387	.373	.413	.101	.424	.378	.491	.457	.551	.607	1.000	
15. Y2 reason	.337	.198	.320	.397	.394	.397	.116	.425	.189	.354	.325	.573	.545	.459	1.000
Mean z	.227	.070	.073	.072	.077	.055	-.030	.195	.076	.0184	.088	.078	.128	-.277	-.077
SD	1.058	.909	.954	.977	1.018	1.002	.814	1.012	.969	.977	.972	.963	.919	1.006	.896

R = .121, p < .01; R = .139, p <.001.

Supplementary Table 1B. Correlations between the variables used in structural equation modeling (boys, N=610).

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Draw per	1.000														
2. Pictures	.282	1.000													
3. Sequences	.258	.382	1.000												
4. Matching	.367	.381	.336	1.000											
5. Counting	.318	.312	.417	.378	1.000										
6. Sums A	.344	.371	.496	.434	.547	1.000									
7. Sums B	.128	.078	.166	.178	.183	.253	1.000								
8. Writing	.521	.342	.348	.448	.455	.452	.218	1.000							
9. Ideas Read	.294	.516	.338	.410	.268	.381	.089	.337	1.000						
10. Letters	.327	.263	.348	.427	.553	.487	.288	.563	.269	1.000					
11. Phonics	.321	.450	.453	.438	.430	.436	.179	.437	.422	.431	1.000				
12. Y2 Math	.379	.385	.326	.442	.489	.517	.198	.482	.406	.516	.466	1.000			
13. Y2 Read	.422	.365	.346	.457	.507	.510	.216	.524	.364	.607	.498	.748	1.000		
14. Y2 Vocab	.322	.480	.330	.377	.397	.436	.145	.425	.420	.501	.494	.617	.639	1.000	
15. Y2 Reason	.319	.313	.328	.380	.411	.400	.171	.384	.298	.388	.412	.580	.562	.464	1.000
Mean z	-.142	-.051	-.045	-.049	-.063	-.040	.023	-.125	-.040	.011	-.07	.045	-.142	-.085	.160
SD	.944	1.102	1.025	1.007	.975	1.002	1.118	.981	1.008	1.023	1.017	1.047	1.034	1.151	1.018

R = .086, p < .03; R = .172, p <.0001.

Supplementary Table 2A. Correlations between the variables used in structural equation modeling (the two younger age groups, N=491).

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Draw per	1.000														
2. Pictures	.312	1.000													
3. Sequences	.195	.292	1.000												
4. Matching	.379	.365	.314	1.000											
5. Counting	.320	.302	.388	.367	1.000										
6. Sums A	.249	.346	.455	.404	.553	1.000									
7. Sums B	-.010	.057	.088	.092	.091	.128	1.000								
8. Writing	.504	.357	.260	.419	.472	.397	.166	1.000							
9. Ideas Read	.273	.520	.352	.434	.299	.350	.043	.343	1.000						
10. Letters	.320	.247	.378	.433	.538	.460	.205	.527	.275	1.000					
11. Phonics	.311	.441	.391	.432	.442	.440	.103	.450	.414	.437	1.000				
12. Y2 Maths	.345	.335	.272	.430	.438	.446	.093	.475	.352	.509	.433	1.000			
13. Y2 Reading	.413	.344	.307	.434	.434	.436	.092	.524	.331	.575	.486	.704	1.000		
14. Y2 Vocab	.298	.439	.381	.376	.386	.423	.050	.441	.446	.515	.508	.637	.659	1.000	
15. Y2 Reason	.274	.307	.273	.386	.364	.343	.087	.388	.253	.378	.378	.558	.540	.509	1.000
Mean z	-.126	-.041	-.132	-.162	-.164	-.165	-.090	-.152	-.066	-.090	-.150	-.168	-.199	-.267	-.086
SD	.928	1.105	.999	1.028	.901	.987	.703	.993	1.042	.953	1.007	1.011	.988	1.079	.959

R = .10, p < .01; R = .169, p <.0001.

Supplementary Table 2B. Correlations between the variables used in structural equation modeling (the two older age groups, N=582).

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Draw per	1.000														
2. Pictures	.293	1.000													
3. Sequences	.280	.314	1.000												
4. Matching	.366	.353	.355	1.000											
5. Counting	.319	.340	.394	.420	1.000										
6. Sums A	.393	.416	.420	.393	.477	1.000									
7. Sums B	.108	.023	.182	.159	.119	.216	1.000								
8. Writing	.584	.284	.301	.416	.408	.434	.171	1.000							
9. Ideas Read	.281	.403	.275	.375	.233	.291	.070	.299	1.000						
10. Letters	.378	.243	.324	.433	.501	.446	.247	.526	.226	1.000					
11. Phonics	.396	.459	.408	.451	.427	.447	.148	.395	.374	.377	1.000				
12. Y2 math	.401	.379	.324	.446	.464	.477	.199	.474	.390	.485	.449	1.000			
13. Y2 read	.419	.360	.325	.417	.471	.495	.191	.514	.358	.581	.469	.739	1.000		
14. Y2 vocab	.314	.412	.269	.339	.351	.417	.149	.375	.330	.483	.441	.554	.571	1.000	
15. Y2 reason	.307	.239	.303	.356	.391	.398	.157	.346	.226	.364	.338	.567	.531	.472	1.000
Mean z	.140	.036	.123	.146	.136	.146	.074	.152	.076	.102	.123	.251	.125	-.087	.174
SD	1.062	.950	.979	.944	1.053	.994	1.182	.997	.943	1.034	.977	.971	.973	1.100	.970

R = .10, p < .01; R = .169, p <.0001.

Highlights

- Reading, mathematics, and reasoning are distinct but related in preschool and primary school.
- There are extensive changes in reading, mathematics, and reasoning throughout the 5th year.
- General cognitive ability at different phases involves phase-specific characteristics.
- Specific skills (reading) at one age predict general ability later if they represent the formation of general ability.