
PASS Processes and Early Mathematics Skills in Dutch and Italian Kindergarteners

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Evelyn H. Kroesbergen,¹
Johannes E. H. Van Luit,¹ Jack A. Naglieri,²
Stefano Taddei,³ and Elena Franchi³

Abstract

The purpose of this study was to investigate the relation between early mathematical skills and cognitive processing abilities for two samples of children in Italy ($N = 40$) and the Netherlands ($N = 59$) who completed both a cognitive test that measures Planning, Attention, Simultaneous, and Successive (PASS) processing and an early mathematical skills test. Correlations between the PASS processes as measured by the Cognitive Assessment System and math tasks showed that Planning and Simultaneous processing were most related to early math skills. Simultaneous processing was most related to the Piagetian tasks and Planning to the counting tasks. Although some differences were found between the Italian and Dutch group on their scores on both tests, the relations between PASS processes and early math skills were comparable for both groups. The results may have implications for early identification of math learning difficulties.

Keywords

early numeracy, mathematics, PASS theory

Mastery of early math skills is important for the acquisition of mathematical knowledge in later grades (Jordan, Kaplan, Locuniak, & Ramineni, 2007). From a Piagetian perspective, there are four prerequisites for learning math (Van de Rijt & Van Luit, 1998): (a) concepts of comparison, such as greater, most, and less; (b) classification, or the ability to arrange objects in a class or subclass; (c) seriation, or the ranking of objects; and (d) correspondence, or the comparison of quantities by making a one-to-one relation. Additionally, for adequate understanding and operating on numbers, children should also have adequate counting skills. An acoustic counting involves saying number names in sequence and resultative counting is the understanding that the order in which the objects are counted makes no difference and that counting simply informs you about the total number of objects. Although the acquisition of these skills can be attributed to quality

¹Utrecht University, Utrecht, The Netherlands

²George Mason University, Fairfax, VA, USA

³University of Florence, Florence, Italy

Corresponding Author:

Jack A. Naglieri, Department of Psychology, George Mason University, 10340 Democracy Lane, Suite 202, Fairfax, VA 22030, USA

Email: jnaglieri@gmail.com

of instruction, a child's general ability also plays an important role. Traditionally, general ability is measured with traditional intelligence tests.

Recently, researchers have begun to shift focus on other abilities, such as thinking (e.g., De Koning, Hamers, Sijtsma, & Vermeer, 2002), working memory (e.g., Bull & Scerif, 2001; Gathercole & Pickering, 2000), and reconceptualization of intelligence as psychological processes (Naglieri & Das, 1997). These researchers have shown that such abilities, for instance, working memory and executive functions, are important predictors of both basic math skills (e.g., Bull & Scerif, 2001) and preparatory math skills (e.g., Kroesbergen, Van Luit, Van Lieshout, Van Loosbroek, & Van de Rijt, 2009). Naglieri and Das (1997) developed a theory of intelligence in which human cognitive functioning is based on four basic neuropsychological constructs: Planning, Attention, Simultaneous, and Successive (PASS) processing. The test based on this theory, Cognitive Assessment System (CAS; Naglieri & Das, 1997), measures ability as a multidimensional concept, and thus may provide information on specific processes that are somewhat different than those included in a measure of general intelligence (such as the Wechsler Intelligence Scale for Children-III; Wechsler, 1991).

PASS scores have been found to be strongly related to achievement (Naglieri & Das, 1997). Kroesbergen, Van Luit, and Naglieri (2003) found that the PASS profiles of students with math learning difficulties differed from those of students with no such difficulties, particularly on Planning and Successive scales of the CAS. They thus demonstrated the potential value of the multidimensional approach used in the CAS but much more research is needed in this area. For this reason, the relationship between PASS and early development of math skills was examined in this study. We first investigated the relation between the PASS theory as measured by the CAS (Naglieri & Das, 1997) and different aspects of early numeracy as measured with the Early Numeracy Test (ENT; Van Luit, Van de Rijt, & Pennings, 1994). The ENT consists of two parts with four subtests each: Piagetian tasks and counting tasks. It was expected that all four PASS processes would be correlated with scores on tests that measure early mathematics skills. Naglieri and Rojahn (2004) already demonstrated that the different PASS processes are related to basic math skills (correlations between $r = .45$ and $r = .67$), but this study focuses on preparatory math skills. We anticipated that Planning processes are required for making decisions with regard to how to solve a problem and monitor one's performance. Planning processes are therefore required in almost every task, especially when tasks are getting more complex and difficult. We thus expected that planning processes are especially important in the counting tasks of the ENT, because they are more difficult than the Piagetian tasks, and because they require a plan for a successful score. Attention is important to selectively attend to the components of a task and focus on the relevant activities. Attention is necessary in the Piagetian tasks, when the child has to focus on the given pictures and the verbal instructions. For counting, it is important because attention helps children keep track during counting. Simultaneous processes are particularly relevant for tasks that consist of different interrelated elements that must be integrated into a whole, as in the pictures children have to analyze in the Piagetian tasks. It is expected that Simultaneous processes are less relevant in counting. Successive processes are relevant when information has to be processed in a certain order, and thus are probably most important for counting skills. These hypotheses were tested in both a Dutch and an Italian sample. Because the educational systems differ somewhat (see Method section), we expected the Dutch children to perform better on the math test, because they appear to have more experience with preparatory math tasks. We did not expect that the domain-general cognitive test will reveal differences between children from both countries, because the PASS processes are thought to be basic elements of human cognitive function that are not explicitly taught in kindergarten. We anticipated that including samples from two countries could strengthen the findings regarding the relation between PASS and mathematics but based on these small samples, general cross-national comparisons are quite limited.

Method

Participants

Children from two European countries (the Netherlands and Italy) were included in the study. The educational programs in these countries differ in their way of teaching kindergartners. In the Netherlands, 97% of the children enter kindergarten soon after their fourth birthday, and especially in the second year, mathematics is integrated into their daily education. Much attention is given to early academic skills. The Dutch curriculum is based on constructivist principles (e.g., Cobb, Gravemeijer, Yackel, McClain, & Whitenack, 1997). Prerequisite math skills include counting, building with blocks, and discussions of questions involving quantities. These activities that are playful and interactive are necessary for the later curricula, which require some basics in math concepts, understanding of numbers, and knowledge of the sequence of numbers (Van Luit & Schopman, 2000). Dutch children thus get used to tasks, such as counting and Piagetian operations.

Italian children can start kindergarten much earlier, from the age of 2½ years, and remain until the age of 6 years. The government recommends that schools organize the learning goals of every subject, considering on the one hand the abilities of every child and on the other the practical and pedagogic theories that seem to fit the specific goals. In other words, teachers are encouraged to teach all children every subject, in such a way that positive learning outcomes can be expected (Italian Ministry of Public Instruction, 2004). The given learning goals are not associated with any specific pedagogic theory. The specific goals related to early math include counting objects, images, people, and instruction in addition, quantity estimation, and classification. However, because no systematic curriculum is available, the teacher determines what and how the children are taught.

Random samples were selected from children in their final year of kindergarten in the participating schools in both countries. The schools were selected based on their geographic place (little travel time for the assistants), and their willingness to participate. Only regular schools were selected with no atypical populations, to get a representative sample. The Italian kindergartners were selected from two regular elementary schools in the northeastern part of Italy, one in a large city and the other in a moderate one. This resulted in a sample of 40 children, 13 boys and 27 girls (see Table 1). This disproportionate distribution by gender occurred coincidentally. In the Netherlands, 59 children were selected from four regular elementary schools in middle-large cities in the western and central part of the Netherlands. The sample consists of 32 boys and 27 girls. Children with known specific disabilities (such as Attention-Deficit Hyperactive Disorder [ADHD] or Pervasive Developmental Disorder [PDD]) or IQ less than 80 were excluded from both the samples. The socioeconomic status (SES), based on educational level and occupation of both parents, was categorized in low, middle, or high. Children in the samples were of average socioeconomic background (see Table 1). The samples did not differ on age, $t(97) = 0.87, p = .39$, or SES, $\chi^2(2, N = 96) = 1.18, p = .55$. However, the samples did differ in the proportion of boys and girls, $\chi^2(1, N = 99) = 4.54, p = .03$.

Instruments

Early Numeracy Test

The ENT (Van Luit et al., 1994) is a test that measures the level of early mathematical competence in 4- to 7-year-old children. The ENT consists of two parts, each with four subtests.

Piagetian skills. (a) Concepts of comparison: The comparison of quantitative or qualitative characteristics of objects is assessed with these items. The questions evaluate whether children master concepts such as “the most,” “the least,” “higher,” and “lower.” (b) Classification: The

Table 1. Description of the Samples

Sample	Age		Gender		SES		
	Mean	SD	Male	Female	Low	Middle	High
Italian	5.89	0.37	13	27	8	20	10
Dutch	5.81	0.47	32	27	18	26	14
Total	5.86	0.43	45	54	26	46	24

Note: SD = standard deviation; SES = socioeconomic status. Information about SES was not available for 2 Italian children and 1 Dutch child.

classification task determines if children are able to determine similarity or differences among objects and group them according to different attributes. (c) Correspondence: Children are asked to compare amounts by making a one-to-one-relation. (d) Seriation: The ranking of objects in class or subclass based on order is evaluated by these items.

Counting skills. (a) Using counting words: The child's skills counting forward and backward as well as using the cardinal and ordinal numbers are evaluated. (b) Structured counting: These items help determine if the child can correspond numbers with numbers of objects. Children are asked to point to the objects with their fingers while counting. (c) Resultative counting: With this set of items it is determined whether children are capable of determining the total number of objects up to 12 from both structured and unstructured collections. (d) General knowledge of numbers: Being able to use knowledge of the number system in a simple problem situation is also evaluated. Items determine if children are able to use numbers under 20 in simple daily problem situations.

The raw total score (correct answers) is transformed in a competence score from 0 to 100. The instructions were translated into Italian by a native speaker. The internal reliability coefficients are high: .90 to .94. For the construct validity, the progression of scores across age and grade are increasing as expected. The correlations between ENT and Dutch standard tests are satisfactory for criterion-related validity purposes.

Cognitive Assessment System

The CAS is a multidimensional measure of cognitive processing based on the PASS theory of intelligence (Naglieri & Das 1997). A standard score is provided for each cognitive process (Planning, Attention, Simultaneous, and Successive) along with a Full Scale score. The internal reliability coefficients are high, Planning = .88; Attention = .88; Simultaneous = .93; Successive = .93; and Full Scale = .96. The progression of scores across ages is measured. The scores either increase (number of correct answers) or decrease (scores based on time). The scales are described below; for further explanation, see Naglieri & Das, (1997). *Planning* is a process, in which the child takes decisions, selects strategies and uses them, and evaluates solutions for problems. *Attention* is a process by which the individual has to focus on specific stimuli, while there are also other, less-relevant stimuli present. *Simultaneous processing* asks from the child to integrate several different stimuli into a whole. *Successive processing* is a process by which the child integrates stimuli in a specific order.

Procedure

The children were administered Italian- and Dutch-adapted versions of the CAS (Taddei, 2005; Van Luit & Kroesbergen, 1998) and ENT (see Taddei & Naglieri, 2005; Van Luit, Kroesbergen, & Naglieri, 2005), in a counterbalanced order. Both tests were administered by advanced university students, qualified for diagnostic testing and trained by one of the authors, an assistant professor with several years of teaching and training experience. The training included an

introduction on the tests, supervised practice sessions, and a real life practice assessment by the trainee. This assessment was videotaped and afterward discussed with the trainer.

Data Analysis

U.S. norms were used to calculate CAS standard scale scores ($M = 100$, $SD = 15$). The ENT consists of eight subtests, which measure two factors. Reliability analysis on the presented sample showed both scales to be sufficiently reliable ($\alpha = .78$ for the Piagetian scale, and $\alpha = .81$ for the counting scale). Correlation analyses were conducted to test the relations between PASS processes and ENT scores, both for the total group and separately for the Italian and Dutch groups. Moreover, a simultaneous regression analysis was conducted with nationality entered as a dummy variable to control for a possible effect of country. Although no differences between boys and girls were expected (cf. Rojahn & Naglieri, 2006), gender was also entered as a predictor variable, because of the difference in proportion of boys and girls between both samples. Second, several regression analyses were conducted in which one of the PASS scale scores was withheld, to test the relative loss of predictive power of the cumulative PASS scores. In addition, multivariate analysis of variance (MANOVA) was used to test the differences between the Italian and the Dutch groups.

Results

Correlations between the four PASS scales and the CAS Full Scale with the ENT factors provided in Table 2 show that the four PASS processes are significantly related to early numeracy. The CAS Full Scale score was highly correlated with both the Total scale ($r = .69$) and the Piaget ($r = .64$) and Counting ($r = .59$) factors of the ENT. The correlations between CAS and ENT total scores did not differ between the groups from both countries ($z = 1.40$, $p = .16$). Furthermore, none of the correlations between PASS scale scores and ENT scale scores differed between the Italian and the Dutch samples ($p > .05$).

The Planning, Attention, and Simultaneous scales correlated moderately high with ENT Total scale. The correlations between Successive processes and early math were significantly lower than the correlation with the Full Scale ($z = 3.35$, $p < .05$). Regarding the different ENT scales, it was found that the Piaget factor correlated highest with the Simultaneous scale (Planning, Attention, and Successive scale scores were significant lower, $z = 2.40$, 2.48 , and 2.64 , $p < .05$) and ENT Counting factor correlated the highest with the Planning scale standard scores, although this effect was not significant, and the lowest with the Successive scale score ($z = 2.55$, $p < .01$). In both the Dutch and the Italian sample, it was found that the successive scale score was significantly lower than the Full Scale score ($z = 1.77$ and $z = 3.30$, respectively; $p < .05$). Regarding the Piaget and Counting scales, no differences between correlations with the PASS scale scores was found, whereas in the Italian sample the low correlation between counting and successive processing was also found ($z = 2.63$, $p < .05$).

Regression analysis with the four PASS scales, nationality, and gender as predictors and ENT scores as dependent variable indicated that all four PASS processes contributed significantly to the prediction of math scores, but not nationality and gender. The four PASS processes together explained 46.5% of the variance in early math skills (see Table 3). When the Full Scale score was entered first in a stepwise regression analysis, the PASS subtest scores could add another 5.4% to the explained variance (R^2 change from 42.0 to 47.4, $p = .07$). When Planning, Attention, Simultaneous, and Successive scales were alternately removed, R^2 changed from 46.5 to 43.6, 42.8, 41.5, and 41.4, respectively.

The differences between the Italian and Dutch samples were investigated in more detail. The CAS standard scores for the Italian and Dutch samples are presented in Table 4. A 2×2

Table 2. Correlations Between PASS Processes and ENT Factors

	Piaget	Counting	Total
Total sample (<i>N</i> = 99)			
Planning	.39**	.48**	.52**
Attention	.38**	.43**	.52**
Simultaneous	.54**	.41**	.46**
Successive	.36**	.30*	.34**
Full Scale	.64**	.59**	.69**
Dutch sample (<i>n</i> = 59)			
Planning	.39**	.49**	.55**
Attention	.27*	.28*	.33*
Simultaneous	.38**	.22	.34**
Successive	.36**	.28*	.29*
Full Scale	.52**	.48**	.56**
Italian sample (<i>n</i> = 40)			
Planning	.43**	.49**	.52**
Attention	.44**	.47**	.52**
Simultaneous	.44**	.43**	.52**
Successive	.36**	.13	.16
Full Scale	.61**	.63**	.73**

Note: PASS = Planning, Attention, Successive, and Simultaneous processes; ENT = Early Numeracy Test.

* $p < .01$. ** $p < .001$.

Table 3. Regression Analysis on the Early Numeracy Test Total Score (*N* = 99)

	<i>B</i>	Standard Error	β
Nationality	1.79	2.32	.08
Gender	0.41	1.76	.02
Planning	0.23	0.10	.25*
Attention	0.30	0.12	.26*
Simultaneous	0.19	0.09	.23*
Successive	0.19	0.07	.23*

* $p < .05$.

(Gender \times Nationality) analysis of variance (ANOVA) revealed a significant effect of nationality on the CAS Full Scale, $F(1, 95) = 24.43$, $p < .01$, $\eta^2 = .21$, but no effect of gender, $F(1, 95) = 0.07$, $p = .79$, or an interaction effect, $F(1, 95) = 0.04$, $p = .85$. A 2×2 (Gender \times Nationality) MANOVA was conducted on the PASS scale scores. The MANOVA showed a significant main effect of nationality, $F(4, 92) = 15.84$, $p < .01$, $\eta^2 = .41$, but no effect of gender, $F(4, 92) = 0.10$, $p = .98$ or an interaction effect of Gender \times Nationality, $F(4, 92) = 0.51$, $p = .73$.

Univariate ANOVA showed that the Italian children scored on average lower than the Dutch children on two of the four PASS scales: Simultaneous and Successive processing. No differences between the groups were found on Planning or Attention. Further analyses showed that the difference between groups was consistent across the three simultaneous subtests, but only in one of the three successive subtests, namely Speech Rate, on which the Italian mean was 6.55 ($SD = 1.41$) and the Dutch mean 11.42 ($SD = 2.29$).

The mean ENT scores presented in Table 4 provide a comparison of the groups to help determine if the Dutch children acquired math skills earlier than the Italian kindergartners. A 2×2 (Gender \times Nationality) ANOVA revealed a significant effect of nationality on the CAS Full

Table 4. Mean Scores and Standard Deviations of Italian and Dutch Kindergartners

PASS scale ^a	Italian (N = 40)		Dutch (N = 59)		<i>d</i> ^b
	Mean	SD	Mean	SD	
Planning	95.93	12.25	96.86	11.92	0.08
Attention	104.00	11.85	103.36	8.35	-0.06
Simultaneous	98.10	12.68	113.42	9.71	1.46*
Successive	91.75	11.68	104.97	12.30	1.10*
Full Scale	95.50	10.40	105.83	9.48	1.04*

Note: PASS = Planning, Attention, Successive, and Simultaneous processes; SD = standard deviation.

a. Normative mean = 100, SD = 15.

b. $d = (M_1 - M_2) / \sigma_{\text{pooled}}$

* $p < .01$ (Bonferroni correction).

Table 5. Mean Scores and Standard Deviations of Italian and Dutch Kindergartners

ENT factors ^a	Italian (N = 40)		Dutch (N = 59)		<i>d</i> ^b
	Mean	SD	Mean	SD	
Piaget*	3.89	0.73	4.44	0.49	0.94
Counting	3.00	1.14	3.51	0.87	0.53
Total*	67.23	12.27	74.47	9.44	0.69

Note: ENT = Early Numeracy Test; SD = standard deviation.

a. Scores range from 0 to 5 for the factor scales and from 0 to 100 for the total score.

b. $d = (M_1 - M_2) / \sigma_{\text{pooled}}$

* $p < .02$ (Bonferroni correction).

Scale, $F(1, 94) = 10.98$, $p < .01$, $\eta^2 = .11$. but no effect of gender, $F(1, 94) = 0.23$, $p = .63$, or an interaction effect, $F(1, 94) = 0.25$, $p = .62$. The Dutch children scored more than seven points higher than the Italian children. A 2×2 MANOVA on the Piagetian and the counting factor showed a significant main effect of nationality, $F(2, 93) = 11.04$, $p < .01$, $\eta^2 = .19$, but no effect of gender, $F(2, 93) = 0.84$, $p = .43$ or an interaction effect of Gender \times Nationality, $F(2, 93) = 1.21$, $p = .30$. Analyses of variance revealed a significant difference between the mean ENT total scores of the Dutch and the Italian children (see Table 5). Further analyses of the factors show that the groups differ significantly only on the Piagetian scale, and not on the counting factor. Within the Piagetian tasks, the groups differed on all Piagetian tasks except comparison.

Discussion

The aim of this study was to investigate the relationships among PASS cognitive processes and early math skills. The math scores measured with the ENT correlated significantly, as expected, with the PASS processes as measured by the CAS. Together, these four processes explained 46.5% of the variance in early math scores of the children. This is the same amount of explained variance as Naglieri and Rojahn (2004) found between basic math and the PASS processes in a study with older children (5 to 17 years). An unexpected result in our study was that Successive processing did not play a large role in the counting tasks. Apparently, when counting is not yet automatized, Planning and executing strategies are more important for success (e.g., Bull & Scerif, 2001). A second finding was that Simultaneous processes are important in Piagetian tasks. This result is not unexpected, because the presentation of the Piagetian tasks is mostly

visual-spatial and therefore demands Simultaneous processing. In previous research, the relation between visuospatial working memory and mathematics was not found (e.g., Bull & Scerif, 2001; Kyttälä, Aunio, Lehto, Van Luit, & Hautamäki, 2003). The specific processes underlying the tests used in the present study, could explain this difference, and these findings stress the need for more research in this area.

An unexpected result was that the Dutch children performed significantly higher than the Italian sample on one Successive subtest and on the Simultaneous scale. A possible explanation for the difference in Speech Rate can be found in the nature of the Italian language, in which only few one-syllable words can be found and children do take longer to say three two-syllable words than three one-syllable words (Naglieri, 2009). This is in line with previous research, which revealed that cultures with short word length have higher digit span than those with longer word length (Baddeley, Thomson, & Buchanan, 1975; Naveh-Benjamin & Ayres, 1986). A possible explanation for the unexpected high score of the Dutch children on the Simultaneous scale may be related to the differences between the particular samples or that the Simultaneous subtests require processes that have been trained in the cognitive-oriented curriculum in the Netherlands. These results, however, need to be interpreted in light of the fact that the samples were small and may not be representative for both countries.

The results of this study should be interpreted with caution for several reasons. First, the samples were relatively small and the compositions of the samples were different. Second, for the CAS, original U.S. norms were used for the Dutch and Italian subsamples because national norms are not yet available for both of these countries. Additionally, detailed observation of the math lessons in the schools could give a better indication of what is exactly taught in these schools and if these practices are representative for both countries. Despite the random selection of the samples, unexpected differences were found and it is possible that the two groups may not be representative of their respective country.

In summary, this initial examination suggests that PASS processing and early math performances are related. Importantly, different PASS processes appear to relate to different aspects of early math skills. This, in turn, suggests that specific PASS processing weaknesses, such as Planning and Attention weaknesses found for children with ADHD (Naglieri & Das, 2005; Van Luit et al., 2005), may have similar relevance to success and failure in early mathematics as they do in subsequent years (Naglieri & Rojahn, 2004). These results also suggest that these basic PASS cognitive processes may be useful for early identification of children at risk for later math problems (Kroesbergen, Van de Rijdt, & Van Luit, 2007). Further research is necessary to determine the stability of this finding and the possible implications of this finding, particularly given the size of the samples.

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