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Rapid Naming Tests: Developmental Course and Relations with Neuropsychological Measures

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A Digits Rapid Automatized Naming (RAN) test and a Colors and Shapes Rapid Alternating Stimulus (RAS) test were administered to 904 Portuguese, normally achieving children (ages 7 to 15), in order to examine these tests scores developmental course. The results showed that the two tests have slightly different developmental trajectories. In addition, the two tests associations with a large number of neuropsychological measures were determined in three age groups (7-9 years, *n* = 301; 10-12 years, *n* = 299; 13-15 years, *n* = 304). The neuropsychological measures addressed attention/executive functions, motor behavior, verbal memory, visual memory and language. The results indicated that each one of the rapid naming tests brings into play not entirely coincident processes. Although, they converge in terms of their associations with language and attention measures, Colors and Shapes RAS test is more demanding in cognitive and linguistic terms. In addition, while Digits RAN test has little in common with short-term memory, Colors and Shapes RAS test relates moderately with short-term memory, due to the increased demands in terms of effort, access and retrieval of the phonological labels that correspond to the different stimuli categories. The need to differentiate between the two rapid naming tests is supported.
Keywords: Rapid Naming Tests.

Se administró una prueba de denominación rápida automatizada de dígitos y una prueba de estímulos rápidos alternantes de color y forma a una muestra normalizada de 904 niños portugueses de entre 7 y 15 años de edad con el objetivo de comparar las puntuaciones de estas pruebas en el curso del desarrollo evolutivo. Los resultados mostraron que las dos pruebas diferían sensiblemente a lo largo del desarrollo. Adicionalmente, se estudió la relación entre estas dos pruebas y un amplio número de medidas neuropsicológicas en tres grupos de edad (7-9 años, *n* = 301; 10-12 años, *n* = 299; 13-15 años, *n* = 304). Estas medidas estaban dirigidas a medir atención/funciones ejecutivas; conducta motora; memoria verbal; memoria visual y lenguaje. Los resultados mostraron que las pruebas de denominación rápida no siempre ponen en marcha los mismos procesos. Aunque coinciden en sus asociaciones con medidas de lenguaje y atención, la prueba de colores y formas (RAS) es más exigente en lo que respecta a aspectos cognitivos y lingüísticos. Además, mientras la prueba de dígitos (RAN) tiene poco en común con la memoria a corto plazo, la prueba de colores y formas (RAS) se relaciona moderadamente con esta media debido a su incremento de exigencias en términos de esfuerzo, acceso y recuperación de etiquetas fonológicas correspondientes a las diferentes categorías del estímulo. Los resultados apoyan la necesidad de diferenciar entre las dos pruebas de denominación rápida.
Palabras clave: Pruebas de denominación rápida

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From the seventies (Denckla & Rudel, 1974, 1976a, 1976b) until the present, rapid naming assessment instruments have registered a large diffusion and use. Rapid naming is assessed by tests or tasks in which the child is required to name visual stimuli, presented in a linear sequence, as quickly as possible. The stimuli are familiar and each one is randomly repeated several times. Generally, the stimuli are letters, digits, colors or common objects, each presented in a separate test. The instruments, that contain a single type of stimuli and require access to a single semantic category, are known as *Rapid Automatized Naming* (RAN). Other kind of rapid naming tests combine stimuli from different and alternated semantic categories within the same test requiring, for instance, the alternated naming of digits and letters or shapes and colors. These instruments, that require access to two or more semantic categories, are known as *Rapid Alternating Stimulus* (RAS).

The relation between the performance in tasks or tests of rapid naming and reading has been extensively studied, and it has been demonstrated that rapid naming correlates with reading (Manis, Doi & Bhadha, 2000). Moreover, it constitutes a predictor of future reading skills (Meyer, Wood, Hart & Felton, 1998b; Wolf, Bally & Morris, 1986) and differentiates, in a consistent way, students with and without reading disabilities (Korkman, Kirk & Kemp, 1998), dyslexic students and students with a normal academic performance of the same chronological age (Fawcett & Nicolson, 1994) and cases with varying degrees of reading disability (Manis et al., 2000; Meyer et al., 1998b; Wolf, 1986).

Furthermore, naming speed differences distinguish dyslexic readers from peers across all languages studied to date, including German (Landerl, 2001), Finnish (Korhonen, 1995), and Dutch (Van den Bos, 1998). The importance of studying rapid naming in languages with higher levels of orthographic regularity than English, such as those just mentioned, is that they provide a means of examining the influence of rapid naming when phonological demands are diminished. In these circumstances, research indicates that rapid naming deficits are one of the main characteristics of reading disabled children (Escribano, 2007; Jiménez et al., 2008; Korhonen, 1995; Landerl, 2001; van den Bos, 1998), and rapid naming becomes a more efficient predictor of reading performance than phonological awareness (de Jong & van der Leij, 1999, 2002; Di Filippo et al., 2005; Escribano, 2007; Landerl, 2001; van den Bos, 1998).

In addition, the performance in tasks or tests of rapid naming has shown to differentiate, in a significant way, children with other learning and/or behavior problems and children from control groups. We refer to children, for instance, whose learning disabilities concern other academic domains besides reading (Waber, Wolff, Forbes & Weiler, 2000); children with and without Attention Deficit and Hyperactive Disorder (ADHD; Carte, Nigg & Hinshaw, 1996); children with and without the Hyperactive (Semrud-Clikeman et al., 2000) or the Inattentive forms of ADHD (Weiler, Bernstein, Bellinger & Waber, 2000); children with ADHD and reading problems and children with the same disorder (ADHD), but without reading problems (Tannock, Martinussen & Frijters, 2000); children with and without language disorders (Wiig, Zureich & Chan, 2000). This large differentiating power has led, inclusively, Waber et al. (2000) to point out that a poor result in rapid naming tests could be viewed as an effective indicator of neurodevelopmental vulnerability to several learning or information processing problems.

In spite of rapid naming's differentiating power or its relations with the learning of reading, there are still many open questions regarding it, amongst which we stress the ones concerning its developmental course, the skills it effectively assesses or the processes underlying different kinds of tasks or tests of rapid naming.

Therefore, and as far its developmental course is concerned, it is possible to observe that the research related to the development of rapid naming skills reveals three essential characteristics. Firstly, there are several studies that included a small or narrow number of school grades or age levels (Denckla & Rudel, 1974; Korkman, Barron-Linnankoski & Lahti-Nuuttila, 1999; Meyer, Wood, Hart & Felton, 1998a; Wagner, Torgesen & Rashotte, 1994; Wolf et al., 1986), but few that included a large number of age levels. These last investigations comprehend: in the United States, the studies of Wolf and Denckla (2005) and of Wiig et al. (2000), whose samples contained, respectively, 1461 individuals from ages 5-0 through 18-11 and 2450 individuals from ages 6 through 21; in the Netherlands, a study developed by van den Bos, Zijlstra and lutje Spelberg (2002), which included a total of 629 individuals with mean chronological ages of 8, 9, 10, 12, 16 and 46 years old. In general, the studies, that employed several kinds of stimuli, indicated that digits naming and letters naming developments were faster, and followed, at greater distance, by colors and objects naming (Denckla & Rudel, 1974; Meyer et al., 1998a; van den Bos et al., 2002; Wolf et al., 1986; Wolf & Denckla, 2005). In addition, the few studies which investigated age levels beyond 10-12 years differ on the specific ages in which the maximum speeds, or asymptotes, may be reached for different stimuli. For instance, as far as digits naming is concerned, Meyer et al. (1998a) and van den Bos et al. (2002) observed that maximum speed was reached respectively around 8th grade and age 16, while the examination of the mean raw scores obtained by Wolf and Denckla (2005) indicates a floor effect at the age of 14.

Secondly, many of these studies have resorted to the administration of RAN tests, and only four studies (Korkman et al., 1999; Wagner et al., 1994; Wiig et al., 2000; Wolf & Denckla, 2005) have analysed the developmental progression of RAS tests. However, in this

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last case, the stimuli that have to be named in each of the studies are very different among themselves regarding, for instance, colors, shapes and sizes (Korkman et al., 1999), colors and shapes (Wiig et al., 2000), letters and digits (Wagner et al., 1994; Wolf & Denckla, 2005), or letters, digits and colors (Wolf & Denckla, 2005), what obviously precludes any obtained results comparisons or conclusions.

Thirdly, there is a strong preponderance of studies conducted with English speaking individuals. It is unknown whether the developmental data obtained apply to other languages.

In regard to the skills that rapid naming tests assess, several explaining hypothesis have been advanced and important debates have occurred without, however, a consensus being reached. Research in this area is based originally on work in neuropsychology and neurology, stemming from a hypothesis by Geschwind (1965). He assumed that color naming could be the best predictor of reading, since both tasks required connecting visual stimuli with verbal labels and were lost through the same lesions. Denckla and Rudel (1976a, 1976b) examined this hypothesis in a series of studies and concluded that rapid naming deficits reflected lack of automaticity in lower level subprocesses, such as feature recognition and name access. Research on impaired naming by aphasic patients has also shown that the retrieval of words from lexical storage includes an extensive ensemble of components and is sensible to any underlying disruption (Goodglass & Kaplan, 1972).

More recently, Wagner and collaborators (Wagner, Torgesen, Laughton, Simmons & Rashotte, 1993; Wagner et al., 1994) considered that rapid naming, together with phonological awareness and phonological memory is one of the components of phonological processing, since it involves efficient retrieval of phonological information from long-term or permanent memory. Nevertheless, it has not yet been established if rapid naming is total or only partially phonological (Cutting & Denckla, 2001; Wolf et al., 2002), that is to say, if it involves other processes besides those implied in the use of phonological information.

Another explaining hypothesis, proposed by Kail and collaborators (Kail & Hall, 1994; Kail, Hall & Caskey, 1999), suggests that rapid naming constitutes, essentially, a processing speed measure. As children develop, they process information more rapidly and, therefore, they name digits, colors, or any other stimuli of a rapid naming task, faster. Thus, rapid naming would reflect "a global developmental change in the speed with which many cognitive processes are executed" (Kail et al., 1999, p. 311). However, processing speed is not clearly defined, can be operationalized in many different ways and not all the results currently available are compatible with its influence in rapid naming (Bowers & Ishaik, 2003).

According to Denckla and Cutting (1999), another rapid naming explaining hypothesis lies in language executive aspects since, in their opinion, the interrelationship between language and executive functions is, in our current state of knowledge, clearly exemplified by rapid naming.

Wolf and collaborators (Wolf, Bowers & Biddle, 2000; Wolf et al., 2002) pointed out that rapid naming requires several and diversified skills, representing a demanding array of attentional, perceptual, conceptual, memory, lexical and articulatory processes. Precise rapid timing would also be critical for the efficiency of operations within each process and across all processes.

As a summary, it is important to underline that the efforts to understand what rapid naming assesses have given rise to a complex and little consistent set of hypothesis and results. The apparent simplicity of rapid naming tasks and tests, as well as their ease of administration, can be deceptive since, and as several authors have emphasized (Bowers & Ishaik, 2003; Närhi et al., 2005; Wolf et al., 2000), they can be more adequately described as complex.

However, the complexity degree inherent to rapid naming can even be more pronounced, if we consider the possibility that different rapid naming tasks or tests require different processes. In fact, it has been noted that RAN tasks are more simple and automatic and less demanding than RAS tasks, as far as the processes involved are concerned. Thus, the latter would be more demanding in cognitive and linguistic terms (Korkman et al., 1999) and namely in terms of attention (Wiig et al., 2000), memory access (Wiig et al., 2000), executive functions (Närhi et al., 2005) or phonological processing (Närhi et al., 2005). Notwithstanding, the empirical basis that sustains the distinction between these two kinds of rapid naming tasks is restrict since, similarly to what has been indicated in relation to the developmental course of rapid naming, researchers have focused on RAN tasks (Carte et al., 1996; Tannock et al., 2000; Wolf et al., 2002) and thus to the processes inherent to alphanumeric (letters and digits) and non-alphanumeric stimuli (colors, objects, shapes…). In fact, only Närhi et al. (2005) had the opportunity to test and corroborate the need to differentiate different rapid naming tasks by demonstrating that, even if all tasks have a clear multi-component nature, RAS tasks have a closer association with phonological skills and executive functions.

Present Study

Coimbra's Neuropsychological Assessment Battery (Simões et al., 2008) is a comprehensive assessment instrument, directed towards the assessment of Portuguese children's neuropsychological development and functioning. It contains a diversified group of tests which addresses the domains of attention, executive functions, motor behavior, memory and language. In the

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language domain it includes, besides two phonological awareness tests (Elision and Substitution) and a Directions Comprehension test, a Digits Rapid Naming test and a Colors and Shapes Rapid Naming test. The digits naming corresponds to a RAN test and the colors and shapes naming to a RAS test.

This fact, as well as the Battery's varied composition, recent development and standardization in a large sample of Portuguese children, provided the opportunity to analyse the open questions previously mentioned. Therefore, this study aims to examine and compare the developmental course of the two rapid naming tests results in a large age range, that is to say from ages 7 to 15; to analyze their respective correlations patterns with the remaining Battery's tests in order to evaluate the factors related to each of the naming tests.

Method

Participants

The sample selection was based on a random stratified sampling procedure, which took in consideration the following criteria: age (approximately 100 individuals by age level); gender (the same number of girls and boys by age level); residential area (arranged by urban, moderately urban and rural residential areas equal to the Portuguese organization; INE/DGOTDU, 1998); geographic region (arranged by littoral and interior regions similar to the Portuguese population's organization).

Children with special educational needs or that benefited from special education services were excluded.

Table 1 shows the sample characteristics for each rapid naming test, as well as their correspondence with the mentioned criteria. The number of individuals in each age level is comprised between 98 individuals who are 11 years old and 102 that are 13 and 15. In order to examine the rapid naming associations with other neuropsychological measures, and as some of the Battery's tests have specific versions for certain age ranges (ages 7 to 9 and 10 to 15), three age groups were taken into consideration in the correlations' calculus: ages 7-9, 10-12 and 13-15. The first group comprises 301 individuals (150 boys and 151 girls), the second 299 individuals (148 boys and 151 girls), and the third 304 individuals (152 boys and 152 girls).

Materials

Rapid Naming Tests

In each rapid naming test, the child is asked to name, as quickly as possible, 50 visual stimuli displayed on a card and arranged at random, in 5 rows with 10 stimuli each. The exception to the random order rule lies in the fact that no individual stimulus could be followed by itself. Besides, both tests have 10 practice stimuli, which aim to verify if they are familiar to the child and if he or she is really able to name them.

The stimuli of the Digits RAN test are 2, 4, 6, 7 and 9, each presented 10 times. Moreover, the stimuli of the Colors and Shapes RAS test are the circle, rectangle, square and triangle, which present the colors yellow, red, black and green. The shapes circle and rectangle and the colors black and green are repeated 12 times, while the shapes square and triangle and the colors yellow and red are repeated 13 times.

The errors (misnames and omissions) were registered and the naming time was measured with a stopwatch. Time and errors raw scores were used in the analysis of rapid naming developmental course, while time standard score was used in the correlational analysis.

Other Battery's Tests

2 and 3 Signs Cancellation Tests - This test assesses, essentially, selective and sustained attention. The 2 Signs Cancellation Test was administered to children aged from 7 to 9 and the 3 Signs Cancellation Test to children aged from 10 to 15. The material comprises an A3 sheet with 1600 squares arranged in lines and 2 or 3 model squares placed at the top of the sheet (according to whether it is the 2 or the 3 Signs Cancellation Test). The child's task consists of, during 10 minutes, crossing out the squares that are equal to the model squares. The score is determined through a formula that takes into consideration the number of squares correctly crossed, omitted and incorrectly crossed.

Table 1

Sample Characterization

	N	Age	Grade	Gender		Residential Area			Geographical Region	
				M	F	Urban	M.U.[a]	Rural	Litt.[b]	Int.[c]
Digits/Colors and Shapes	904	7-15	1º-10º	451	453	70.7%	16.8%	12.5%	84.1%	15.9%

Note. [a]M.U. = Moderately Urban [b]Litt. = Littoral [c]Int. = Interior

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Trail Making Test – Part A – This test assesses visuospatial sequencing and rapid visual search. The child has to draw a line connecting 25 encircled numbers randomly distributed on a sheet of paper, sequentially from 1 to 25. The score corresponds to the time required to complete the task.

Trail Making Test – Part B – This part of the *Trail Making Test* is more complex than part *A* since it has greater requirements in terms of motor speed and rapid visual search, and also demands mechanisms of cognitive shifting and flexibility. Therefore, in this part the child has to draw a line connecting 25 circles with numbers or letters, randomly distributed in a sheet of paper, alternating between numbers and letters (e. g., 1, A, 2, B, etc.). The score corresponds to the time needed to complete the task.

Corsi Blocks – It is a test of attention and of visual memory with a motor component. The examiner taps with his index finger 9 blocks in a board according to prearranged motor sequences. After that, the child must copy each one of those tapping patterns, within two trials. The score is obtained by adding the points reached in each sequence and trial.

Tower of Coimbra – This test is similar to the Tower of London and assesses the executive functions of planning, monitoring, self-regulation and problem solving. The material comprises 12 models, presented as photographs that the individual has to reproduce in a tower with three balls of different colors. In regard to each model, it is possible to do up to 4 trials. Although it is possible to calculate several scores, the present study only considers the total score, which is determined through a point system that takes into account the trial number in which the child was able to reproduce the model.

Motor Board - This test assesses manual and finger dexterity. The child has to put as many pins as possible in a board with 50 holes, first with the preferred hand (2 trials), then with the nonpreferred hand (2 trials) and at last with the two hands simultaneously. Although it is possible to determine a score for each hand, this study uses only the two hands score, which corresponds to the mean number of pins correctly placed.

Words List – This test assesses the learning ability, retention, recall and recognition of audioverbal material. The child starts by learning a list of 15 words during 4 trials. A new list with 15 words, the interference list, is then presented and recalled once. After that, the child is asked to recall the first word list either immediately (Immediate Recall Trial) or after a 20 to 30 minutes delay (Delayed Recall Trial). Finally, 45 words are presented to the child and he or she must indicate whether the words belong to the first list (Recognition Trial). All the scores of this test are based on the number of correctly recalled or identified words in one or more trials. This study uses the scores related to: immediate recall, delayed recall, recognition and learning (total number of words correctly recalled in the first 4 trials).

Narrative Memory – This test requires the same skills as those mentioned above, as well as planning, organizing, sequencing and language skills. It embraces 4 stories: the ones named A and B were administered to children aged from 7 to 9 and the ones named C and D to children aged from 10 to 15. The examiner reads each story and the child retells it immediately after having heard it (Immediate Recall Trial) and after a delay of 20 to 30 minutes (Delayed Recall Trial). Finally, he or she is asked multiple-choice questions about each story (Recognition Trial). In the Immediate Recall and Delayed Recall Trials, the child is given points for each information unit correctly recalled, whereas in the Recognition Trial she is given points for each correct answer. In addition, the first two scores can be combined in a single score of Immediate and Delayed Recall. All these scores are used in this study.

Memory for Faces – This test assesses the recognition ability of 16 unfamiliar faces. Firstly, the faces are shown to the child and immediately after the last face is presented he or she identifies, within sets of 3 faces, each one of the previously seen faces (Immediate Recall). After 20 to 30 minutes, the child identifies the same faces from different sets of three (Delayed Recall). The score used in this study was the total score, which corresponds to the number of faces correctly recognized in the immediate and delayed recall conditions.

Rey-Osterrieth Complex Figure – This test assesses a variety of cognitive processes (e.g., planning, problem solving, perceptual and motor functions), but its primary purpose is to assess visuospatial constructional ability and visual memory. The procedure adopted consisted in the copy of the Rey-Osterrieth Figure, followed by an Immediate Recall Trial (3 minutes after) and, finally, by a Delayed Recall Trial (20 to 30 minutes after). The recall trials' scores, determined according to the Meyers and Meyers system (1995), were employed in this study.

Semantic Verbal Fluency – This test requires the mobilisation of verbal skills, memory and executive functions. It asks the child to generate as many different words as possible, according to the semantic categories of "animals' names", "boys and girls' names" and "things to eat". The score corresponds to the number of correct words.

Phonemic Verbal Fluency – This test assesses the same skills as Semantic Verbal Fluency, as well as phonological knowledge, since it requires words production according to phonemic categories. Thus, the child has to generate as many different words as possible, beginning with the letters P, M and R. The score corresponds to the number of correct words. In addition to this score and the one related to Semantic Verbal Fluency, this study also uses the total score of Verbal Fluency, obtained by adding the first two.

Elision Test - This is a phonological awareness test, in which the child is asked to say 19 familiar words without a particular phoneme. The score is the number of words correctly pronounced.

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Substitution I and II Tests - It is also a phonological awareness test, with two different versions: the one denominated Substitution I was administered to children aged from 7 to 9 and the one denominated Substitution II to children aged from 10 to 15. In both versions, the child is asked to say familiar words (19 in Substitution I and 17 in Substitution II) after having replaced one or more phonemes for others. The score is the number of words correctly pronounced.

Directions Comprehension Test – This test assesses receptive language, at the semantic and syntactic level, through the child's answer to 27 oral instructions. These 27 instructions contain several concepts (e.g., expressing quantity, sequence, temporal or spatial relationships) and are arranged, in equal number in 3 parts, which involve an increasing conceptual complexity level and different materials. Therefore, the child has to point to: in the 1st part, one or more puppies that differ amongst them in color, size and expression; in the 2nd part, one or more geometrical shapes that have different colors and shapes; and in the 3rd part, one or more geometrical shapes that differ amongst them in color, size and shape. The score corresponds to the number of instructions correctly performed.

Procedure

All the tests were individually administered in two test sessions in a quiet school space.

Psychologists who were fully trained in the tests administration carried out the assessments.

Results

Developmental Course

The analysis of rapid naming developmental course used time and errors raw scores. These scores' distribution revealed positive skewness and the presence of outliers, and both Kolmogorov-Smirnov and Levene´s tests were significant ($p < .05$). In order to reduce the impact of outliers, while maintaining the same number of individuals by age level, the extreme values were Winsorized (Wilcox, 2005). The number of the extreme values that were transformed and their original scores were the following: 11 (1.2%) with scores comprised between 46-56 in digits naming time; 6 (.7%) with scores within 2-10 in digits naming errors; 19 (2.1%) with scores between 208-377 in colors and shapes naming time; 13 (1.4%) with scores within 12-43 in colors and shapes naming errors.

Although Kolmogorov-Smirnov and Levene´s tests remained significant, ANOVA is considered to be robust to violations of normality and homogeneity of variance, with sufficiently large and equal samples sizes (Howell, 2002; Tabachnick & Fidell, 2001). As this was the case in the present study, after transformation of the outliers, an ANOVA was carried out for detecting age differences in rapid naming.

Tables 2 and 3 and Figures 1 and 2 report to raw scores, without transformation of the outliers. The means and standard deviations of the tests' raw scores at several age levels are plotted in Figures 1 and 2.

As far as *Digits RAN test* is concerned, Table 2 and Figure 1 show that mean time diminishes from one age level to the following, with the exception of age 13, in which a slight increase was registered in relation to age 12. Standard deviation also decreases noticeably as a function of age, especially between ages 7 and 10. In addition, an ANOVA, with Tukey post-hoc (F (8, 895) = 139.02, $p < .001$), indicated the following statistically significant differences between two consecutive age levels: 7 and 8 years ($p < .001$), 8 and 9 years ($p < .001$) and 11 and 12 years ($p < .01$). Between two intercalated age levels, the following statistically differences were observed: 7 and 9 years ($p < .001$), 8 and 10 years ($p < .001$), 9 and 11 years ($p < .001$), 10 and 12 years ($p < .001$), 11 and 13 years ($p < .05$) and 13 and 15 years ($p < .01$). When joined, these results show that naming time progresses in a more steady way, between 7 and 12 years, and subsequently shows a more slow development and a gradual stabilization.

Concerning the responses accuracy, the number of errors is very small in any of the age levels (cf. Table 2), as well as the percentages of children that make errors (from 6.9% to 1%), with the highest value occurring at age 7 (6.9%) and the smallest at age 15 (1%). Besides, amongst those that make errors, there is a preponderance of cases with a single error (from 5.9% at age 7 to 1% at age 15). Therefore, an ANOVA, with Tukey post-hoc (F (8, 895) = .98, $p > .05$), did not detect any statistically significant differences in the number of errors as a function of age.

In relation to the *Colors and Shapes RAS test*, Table 3 and Figure 2 show that mean time diminishes with age, in a consistent way. Standard deviation decreases are, once again, more salient at the younger ages, in particular between ages 7-8 and 9-10. An ANOVA, with Tukey post-hoc (F (8, 895) = 146.94, $p < .001$), indicated the presence of statistically significant differences between the two following consecutive age levels: 7 and 8 years ($p < .001$); 8 and 9 years ($p < .001$). When two intercalated age levels were considered, there were statistically significant differences between: ages 7 and 9 ($p < .001$), 8 and 10 ($p < .001$), 9 and 11 ($p <. 01$), 10 and 12 ($p < .01$) and 13 and 15 ($p < .05$). Therefore, in this test, and similarly to what was verified in digits naming, naming time shows greater individual variability and progresses in the younger ages. However, in this case, development becomes slower after age 9, and stabilizes at age 15.

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Table 2

Digits RAN Test – Time and Errors

		Time			Errors		
Age	*n*	*M*	*Mdn*	*SD*	*M*	*Mdn*	*SD*
7	101	34.12	34.00	6.67	.16	.00	1.02
8	100	29.89	29.00	6.06	.05	.00	.22
9	100	25.60	24.00	4.62	.03	.00	.17
10	102	24.31	24.00	3.96	.03	.00	.22
11	98	23.17	23.00	4.47	.03	.00	.22
12	99	20.55	20.00	3.92	.04	.00	.20
13	102	21.07	21.00	3.70	.08	.00	.41
14	100	19.15	18.00	3.78	.03	.00	.17
15	102	18.41	18.00	2.77	.01	.00	.10

Table 3

Colors and Shapes RAS Test – Time and Errors

		Time			Errors		
Age	*n*	*M*	*Mdn*	*SD*	*M*	*Mdn*	*SD*
7	101	152.16	138.00	54.80	2.32	1.00	4.12
8	100	122.31	116.00	33.15	1.22	.00	2.15
9	100	102.28	94.50	34.57	.81	.00	1.73
10	102	93.16	92.50	16.61	1.36	.00	4.56
11	98	86.66	86.00	14.80	1.08	.00	2.46
12	99	78.71	76.00	15.06	.73	.00	1.31
13	102	77.44	76.50	14.64	.87	.00	1.72
14	100	71.31	70.00	12.97	.58	.00	1.09
15	102	67.34	66.00	11.40	.59	.00	.95

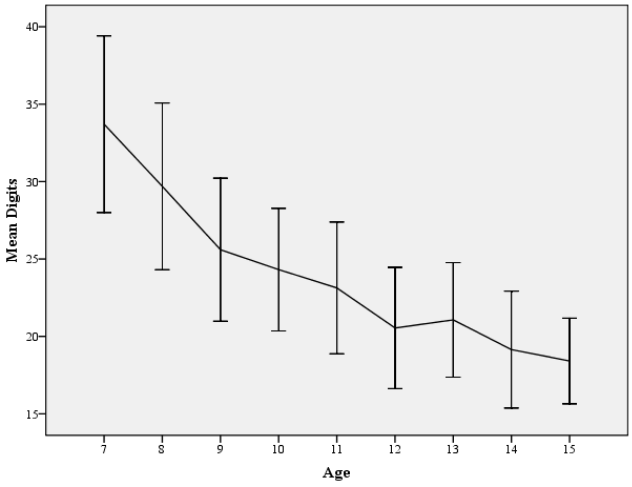


Figure 1. Scatterplot showing Mean time against age for the Digits RAN test. Vertical bars indicate ±*SD*.

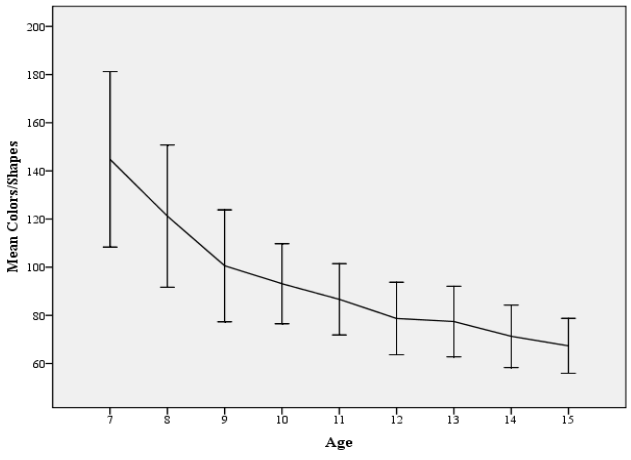


Figure 2. Scatterplot showing Mean time against age for the Colors and Shapes RAS test. Vertical bars indicate ±*SD*.

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As far as responses accuracy is concerned, and contrary to what happens in the Digits RAN test, the number of errors takes on some importance and the percentages of children that make errors are considerable, oscillating between a maximum of 63.4% at age 7 and a minimum of 32% at age 14. Amongst those that make errors, there is a preponderance of cases with a single error (from 26.5% at age 15 to 16% at ages 9 and 14) or 2 errors (from 21.8% at age 7 to 7.1% at age 12). Nevertheless, the percentages of those that make 3 or more errors, at age 7 (21.8%), 8 (13%), 10 (9.8%) and 13 (9.8%), are worth registering.

In general, the average number of errors diminishes with age, although there are slight ascending trends at ages 10, 11 and 13, when compared to one or two of the preceding age levels (cf. Table 3). An ANOVA, with Tukey post-hoc (F (8, 895) = 5.87, $p < .001$), revealed statistically significant differences in the mean number of errors between age 7 and all the remaining age levels ($p < .01$ for the ages 10 and 11; $p < .001$ for the ages 9, 12, 13, 14 and 15), with the exception of age 8.

Correlations with neuropsychological measures

This analysis used time standard scores of the rapid naming tests and the standard scores of the other Battery´s tests. These standard scores have a mean of 10 and a standard deviation of 3 in each age group and were derived in the following manner: raw scores frequency distributions were first constructed for each age and test; raw scores were converted into percentile ranks; the percentile ranks were converted to normalized z-scores; these scores were then re-scaled in order to achieve the desired mean and standard deviation.

The standard scores distributions did not present outliers, they showed skewness in a very small number of cases (Trail Making Test - Part A and Part B in all age groups; Words List - Recognition and Elision at ages 10-12 and 13-15), and the examination of the scattergrams did not reveal lack of linearity between variables in all the pairs under analysis.

As previously mentioned, the correlations were separately calculated for each of three age groups: ages 7-9, 10-12 and 13-15. Although the total number of individuals in these age groups is, respectively, 301, 299 and 304, there are slight oscillations in these sample sizes, only due to the exclusion of incomplete Record Forms of a few tests.

In order to facilitate results' organization and presentation, the tests were grouped according to the neuropsychological domain to which they pertain (attention/executive functions; motor behavior; verbal memory; visual memory and language). However, we stress this grouping approximate nature, considering that the Battery factorial structure is still being studied, that no test is a pure measure of a single neuropsychological domain and also that the literature is inconsistent in the framing of tests with a clear multifactorial nature. One of the most obvious examples of this inconsistency lies in the verbal fluency tests that, similarly to other authors (Korkman et al., 1998; Lezak, Howieson & Loring, 2004), we have integrated in the language domain, but that can also be found included in the executive functions domain (Baron, 2004; Spreen & Strauss, 1998).

In regard to the Pearson correlations that figure in Table 4, we start by noting that they are invariably low or moderate. Secondly, the values concerning digits naming, when compared to colors and shapes naming values are, with few exceptions, systematically inferior. The exception that is present in all three age groups and that can, therefore, be considered the most consistent, refers to the Trail Making Test - Part A. In addition, colors and shapes naming presents statistically significant correlations with almost all the Battery's tests, while digits naming presents significant correlations with a small number of Battery's tests. To be more specific, colors and shapes naming just does not significantly correlate with the Trail Making Test - Part A (7-9 years), the Motor Board (10-12 years) and the Tower of Coimbra (13-15 years) in one age group, with Memory for Faces (7-9 years and 13-15 years) and the Rey-Osterrieth Immediate Recall (7-9 years and 10-12 years) in two age groups, and with the Rey-Osterrieth Delayed Recall in all three age groups. On the other hand, digits naming does not significantly correlate with Corsi Blocks (13-15 years) and the Elision test (13-15 years) in one age group, with the Directions Comprehension test (10-12 years and 13-15 years) in two age groups, and with the Tower of Coimbra, several results of the Words List, Narrative Memory, Memory for Faces and the Rey-Osterrieth Complex Figure in all three age groups.

Thirdly, although all the correlations are uniformly low or moderate, as it has been noted, the highest among them concern language and attention/executive functions tests. So, the highest correlations of digits naming refer to verbal fluency (phonemic, semantic and total), to phonological awareness (Elision and Substitution I at ages 7-9), and to attention (Trail Making Test - Part A at ages 10-12 and 13-15; 2 and 3 Signs Cancellation test). As for colors and shapes naming, they report to attention (2 and 3 Signs Cancellation tests; Trail Making Test - Part B at ages 13-15), verbal fluency (semantic and total), phonological awareness (Substitution II) and receptive language at the semantic and syntactic levels (Directions Comprehension at ages 7-9 and 13-15).

Fourthly, the correlations pattern is very similar across all age groups, showing very slight fluctuations. Nevertheless, colors and shapes naming reveals a tenuous trend towards presenting higher correlations with most of the attention/executive functions tests, with verbal memory tests and the Directions Comprehension test in the oldest age group.

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Table 4

Correlations between Rapid Naming Tests and other Battery's Tests

	7/9 Years (n = 301)[a]		10/12 Years (n = 299)[b]		13/15 Years (n = 304)[c]	
	D[d]	C/S[e]	D[d]	C/S[e]	D[d]	C/S[e]
Attention/Executive Functions Tests						
2 Signs Cancellation	.20**	.32**				
3 Signs Cancellation			.21**	.34**	.19**	.42**
Trail A	.16**	.09	.25**	.18**	.22**	.19**
Trail B	.13*	.18**	.15*	.27**	.18**	.37**
Corsi Blocks	.12*	.16**	.16**	.14*	.11	.20**
Tower of Coimbra	.06	.16**	.07	.14*	-.02	.03
Motor Behavior Test						
Motor Board	.18**	.24**	.18*	.05	.16**	.13*
Verbal Memory Tests						
Words List – Immediate	.05	.19**	.02	.18**	.07	.15*
Words List – Delayed	.08	.21**	.05	.18**	.04	.14*
Words List – Recognition	.14*	.18**	.06	.17**	.10	.21**
Words List – Learning	.11	.23**	.07	.16**	.10	.24**
Narrative Memory A/B – Immediate	-.01	.15**	.			
Narrative Memory A/B – Delayed	-.02	.12*				
Narrative Memory A/B – Recognition	.00	.18**				
Narrative Memory A/B - Immediate and Delayed	-.01	.15**				
Narrative Memory C/D – Immediate			.03	.17**	.10	.27**
Narrative Memory C/D – Delayed			-.00	.17**	.09	.29**
Narrative Memory C/D – Recognition			.04	.14*	.00	.18**
Narrative Memory C/D - Immediate and Delayed			.02	.17**	.10	.28**
Visual Memory Tests						
Memory for Faces	.06	.10	.07	.11*	.05	.06
Rey Figure – Immediate	.04	.06	-.06	.06	-.02	.13*
Rey Figure – Delayed	-.02	.04	-.08	.09	-.07	.11
Language Tests						
Phonemic Fluency	.22**	.20**	.22**	.24**	.18**	.18**
Semantic Fluency	.24**	.36**	.26**	.29**	.29**	.32**
Verbal Fluency Total	.28**	.35**	.28**	.31**	.28**	.31**
Elision	.22**	.26**	.12*	.16**	.08	.22**
Substitution I	.22**	.28**				
Substitution II			.15*	.27**	.15**	.34**
Directions Comprehension	.12*	.33**	.08	.17**	.06	.37**

Note. [a] Except in the Trail B (n = 297) and the Tower of Coimbra (n = 296). [b] Except in the Trail B (n = 298), the Motor Board (n = 297), Words List - Recognition (n = 298), Elision (n = 298) and Substitution II (n = 298). [c] Except in the Tower of Coimbra (n = 303), Narrative Memory C/D - Recognition (n = 303) and 3 Signs Cancellation (n = 233). [d] Digits. [e] Colors and Shapes.
*p < .05 **p < .01

Discussion

The results obtained concerning the developmental course of rapid naming agree, on the one hand, with those obtained in other studies, since they indicate: a performance improvement with age (Denckla & Rudel, 1974; Meyer et al., 1998a; van den Bos et al., 2002; Wagner et al., 1994; Wolf & Denckla, 2005); that the greatest increase in rapid naming time occur in the initial years of formal schooling (Denckla & Rudel, 1974; Meyer et al., 1998a); a high accuracy in Digits RAN tests, with very small errors percentages in all ages (Denckla & Rudel, 1974; van den Bos et al., 2002); a low accuracy, at the younger ages, in the Colors and Shapes RAS test (Wiig et al., 2000).

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On the other hand, the results obtained complement the ones observed in other studies, since regarding digits naming time, they show a clear progression between the ages of 7 and 12 and a slow progression between the ages 12 and 15, based on a large age range and consecutive age levels. As Wolf and Denckla's (2005) large scale study employed exactly the same digits as the present study, and covered similar age levels, it is possible to observe that there is an obvious similarity between the raw scores of American and Portuguese children, since the American also show small progresses in digits naming after the age of 14.

As far as Colors and Shapes RAS test is concerned, it is worth remembering that only Wiig et al. (2000) used an identical RAS task. Even so, the results obtained are consonant with those described by Wiig et al. (2000) and Wolf and Denckla (2005), but not with those reported by Korkman et al. (1999), since they stress that this test speed and accuracy continues to occur long after the ending of preschool. In fact, when Korkman et al. (1999) analysed the performance, in a Colors, Shapes and Sizes RAS test, of children who attended school from kindergarten until Grade 6, they only noted a single statistically significant difference between two neighbouring grade levels, namely concerning accuracy and occurring in the transition between kindergarten and preschool. As previously noted, the differences observed in this study are larger and concern both accuracy and time: accuracy increases significantly after age 8; and time diminishes significantly between ages 7-9 if two consecutive age levels are considered, and between ages 7-15, if two intercalated age levels are considered. For this reason, our results match those found by Wiig et al. (2000), who also noted that time score only stabilizes at age 15. The mean raw scores, obtained by Wolf and Denckla (2005), in a Letters, Numbers and Colors RAS test also showed small improvements after age 14.

When considered simultaneously, the results obtained stress that the two tests have partially distinct developmental courses: digits naming accuracy is high and stable across ages, while colors and shapes naming accuracy is low at ages 7-8 and improves thereafter; naming time decreases, markedly, between ages 7 and 12 for digits and between ages 7 and 9 for colors and shapes; naming time, in both tests, continues to improve somewhat until age 15.

Regarding the correlations between rapid naming tests and other Battery's tests, the fact that the values obtained are low or moderate indicates that naming tests assess specific skills or skills only partially equivalent to the ones assessed by other neuropsychological tests.

Furthermore, the observed differences between the two tests concerning the significance and size of their correlation coefficients meet the above-mentioned possibility that different naming tests call for not entirely coincident processes.

Therefore, the two naming tests converge at the level of their associations with language and attention tests. In the language domain, the most important values of both tests are related to semantic verbal fluency and the total score of verbal fluency, which are similar to rapid naming in the scope of the requirements of rapid lexical production, automatic access and recall of lexical information, self-control, performance monitoring and also of selective and divided attention. These findings are also congruent with data about the relationship between RAN tasks and reading, particularly in languages with relatively high levels of orthographic transparency. Indeed, in languages such as Dutch (de Jong & van der Leij, 2002), German (Landerl, 2001), Italian (Di Filippo et al., 2005) and Spanish (Escribano, 2007; Jiménez et al., 2008), RAN tasks show a strong association with measures of reading speed and reciprocally RAN deficits primarily affect performance on reading fluency tasks.

Still in the language domain, we stress the associations related to the phonological awareness tests, which are otherwise similar to those pointed out by other authors in non-clinical samples and in relation either to digits naming (Manis et al., 2000; Wagner et al., 1994), or to colors, shapes and sizes naming (Korkman et al., 1999; Korkman et al., 1998).

Moreover, the association between rapid naming and attention tests and in particular the 2 and 3 Signs Cancellation test is explainable in terms of their respective requirements at the levels of selective attention, divided attention and processing speed.

In spite of these convergence points, the Colors and Shapes RAS test has a more marked multi-component nature than the Digits RAN test, being more demanding in terms of attention, cognitive flexibility, memory access and semantic processing. In regard to attention, the correlations with the 2 and 3 Signs Cancellation tests match other author's observations, according to which the naming of alphanumeric stimuli requires an automatic processing (Carte et al., 1996; Wolf et al., 2000), while colors and shapes naming demands, more intensely, selective and divided attentional abilities (Wolf, 1986; Wiig et al., 2000).

In terms of cognitive flexibility, Colors and Shapes RAS test has a higher correlation with the Trail Making Test - Part B than with the Trail Making Test - Part A, while the contrary happens with the Digits RAN test. As noted in the Materials section, Trail Making Test - Part B has additional cognitive requirements when compared with the Trail Making Test - Part A, namely in terms of cognitive flexibility. In this context, we note that colors and shapes naming requires accurate and rapid conceptual shifts between the two categories and their associated semantic fields, which have to be named.

Concerning the relations between short-term memory and rapid naming, the results obtained underline once again that, as digits naming is an automatic task and

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demands a reduced effort, it is independent of a controlled and active process, such as the one represented by the retention and recall of a word list or stories. In fact, although the research concerning the associations between digits naming or digits and letters naming and short-term memory has given rise to contradictory results, several authors have observed, also in non-clinical samples, the presence of low and non-significant correlations between both variables (Cutting & Denckla, 2001; Wagner et al., 1993). Thus, as suggested by de Jong and van der Leij (1999), RAN tasks can have little in common with short-term memory. However, in RAS tasks, such as colors and shapes naming, the increasing demands in terms of effort, access and retrieval of the phonological labels that correspond to the different stimuli categories may support their relationship with short-term memory.

In terms of semantic processing, the Colors and Shapes RAS test, when compared with the Digits RAN test, presents higher correlations with the Directions Comprehension test. This observation can have several explanations. Therefore, firstly it can be a simple artefact, since both tests require, partially overlapping, words, namely colors and shapes. Secondly, it can also be a reflection of the need to access two semantic categories in the case of colors and shapes naming, instead of just one as in digits naming. Thirdly, it is also possible that, similarly to what has been pointed out in relation to the English language (Tannock et al., 2000), colors naming in Portuguese requires more semantic processing than digits naming. Therefore, in relation to English, several facts have been indicated as evidence of colors and digits differential semantic processing demands: the uncertainty of the names that correspond to colors (Johnson, Paivio & Clark, 1996); the slower learning of colors than learning of digits (Denckla & Rudel, 1974; Van den Bos et al., 2002; Wolf et al., 1986); and the difficulties in colors naming, but not in digits naming, that occurs in clinical groups (e.g., ADHD; Tannock et al., 2000).

Conclusion

This study contrasted two rapid naming tests, not only from the point of view of their developmental courses, but also from the point of view of their associations with a large number of neuropsychological tests. A common question underlies both analysis, namely to determine if they are similar instruments.

The results obtained evidence that the two tests have slightly different developmental trajectories, although both show progress as a function of age.

Furthermore, the study underlines that rapid naming tests are complex and involve multiple processes, as those related to attention, access and retrieval of phonological labels, activation and integration of semantic and conceptual information. Consequently, the results match the perspective that rapid naming represents a demanding array of processes (Wolf et al., 2000) and should not be regarded as a single measure of phonological processing, speed of processing or memory.

Regarding whether the two tests require the same or different processes, the correlations obtained stress that they imply only partially overlapping processes. Thus, they converge in terms of their associations with language and attention tests. However, colors and shapes naming is more demanding in linguistic and cognitive terms. In addition, while Digits RAN test has little in common with short-term memory, Colors and Shapes RAS test relates moderately with short-term memory, due to the increased demands in terms of effort, access and retrieval of the phonological labels that correspond to the different stimuli categories. Therefore, the need to differentiate RAN and RAS tests is supported.

However, the specific skills assessed by each rapid naming test remain unexplained, due to the correlational nature of this study, as well as to the low or moderate correlations that were obtained. The factorial analysis of Coimbra's Neuropsychological Assessment Battery, in which rapid naming tests are included, can eventually provide complementary indications. It is also essential to determine if the associations observed in this study are replicated in clinical samples.

To sum up, in spite of the rapid naming tests large diffusion, they are still poorly understood.

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