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Italian neuropsychological instruments to assess memory, attention and frontal functions for developmental age

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Abstract In this study, a series of tests exploring long-term verbal memory (the Short Story Test), attention (a modified version of Attentional Matrices and the Trail Making Test) and frontal functions (a modified version of the Frontal Assessment Battery) have been standardised on an Italian population of 283 children aged 5–14. Raw scores for each test have been adjusted for a series of variables (child's age, years of parents' education, handedness, gender) and transformed in equivalent scores enabling direct comparison across measures. This study was promoted by LICE (the Italian League Against Epilepsy) in order to provide Italian instruments standardised on the developmental age population and to study some of the most frequently impaired cognitive functions in epilepsy.

Key words Epilepsy • Memory • Attention • Frontal functions • School-age children

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Introduction

The aim of the present study is to provide an Italian standardisation of cognitive tests assessing long-term episodic verbal memory (two new parallel versions of the Short Story Test), attention (a modified version of Attentional Matrices and the Trail Making Test) and frontal functions (a modified version of the Frontal Assessment Battery) for children. Until now, only a quite limited range of instruments to assess these cognitive functions have been available with an Italian standardisation [1–5].

We have chosen tests available in the adult neuropsychological literature, which are sensitive in assessing both the cognitive functions under study and their modifications in time. As they can be easily administered to children, even those of a young age, demanding a reasonable amount of time and effort on the part of the child, they were deemed particularly useful in longitudinal studies within a wider neuropsychological battery.

The LICE (Italian League Against Epilepsy) Neuropsychology Study Group promoted this investigation specifically focused on cognitive functions such as memory and attention that are frequently impaired in temporal and frontal epilepsy.

Frontal and temporal lobe maturation has often been analysed in normal children by applying models and tests derived from the study of adults. Evidence from healthy children has shown that the structural and physiological changes occurring during frontal lobe development coincide with increasing efficiency in information processing and activity modulation [6]. A sequential development of

skills has been hypothesised, with simple planning and visual search mastered by the age of 6, hypothesis testing and impulsive responding control achieved not before age 10, while motor sequencing and complex planning continue to develop beyond 12 [7]. On the other hand, the role of hippocampal and parahippocampal regions is progressively clearer: these structures are reciprocally interconnected with the cerebral neo-cortex, and seem to be involved in the organisation of long-term declarative memory, as demonstrated by numerous investigations [8–10]. While the anatomical and functional development of the frontal cortex progresses with time, it seems that the architecture of hippocampal and parahippocampal structures is established in the first period of life: an early lesion of these structures could not be compensated for by the establishment of alternative pathways and the degree of impairment seems to be age-related [11].

Children with epilepsy, depending on the localisation of the epileptogenic zone, often show cognitive deficits, or below-average performance, especially in episodic long-term memory or in attentional tasks [12–19]. For this reason, we decided to elaborate and standardise a revisited battery of tests, in order to offer additional measures for the assessment of long-term verbal memory, attention and frontal functions.

Materials and methods

Sample

Two hundred and eighty-three children, 148 girls and 135 boys, aged 5–14 years, were recruited. Their clinical history was negative for neurological disorders and learning disabilities. Children were randomly selected from the entire population of three schools located in three Italian towns (Milan, Pavia and Livorno). The sample included nine educational levels, from the first year of primary school to the last year of secondary school. In the first-year student group, a sub-categorisation was applied, with 17 subjects being tested in the early months of the school year, 13 halfway along the year, and 20 at the end of the year, in order to be able to take into account the possible effects of teaching. The sample sizes of the other education levels (from 2 to 8, i.e., from second year of primary school to third year of secondary school) were n=32, 35, 38, 35, 35, 34 and 24 respectively (see Table 1).

A handedness index for each subject was established on the basis of which 257 children were classified as right-handed and 26 as left-handed. Parents' education ranged from 5 to 17 years of formal schooling (father's age: range 26–62; mean 42; SD 5.25; father's years of education: mean 12.58; SD 3.38; mother's age: 25–53; mean 39.49; SD 4.57; mother's years of education: mean 12.56; SD 3).

Parents and school teaching staff gave their informed consent for the children to participate in the study.

In order to estimate the test–retest reliability indices, a subset of the sample was re-administered again one week later with all the tests, including the parallel version of the Short Story Test (Session 1 *vs*. Session 2).

Table 1 Descriptive statistics – stratification of the sample according to child's education

Education (years)	*N*	Mean age (years)	Short story				Attentional Matrices				Trail Making Test						FAB	
			Story I		Story II		N		Time		A		A/B		B			
			M	SD	M	SD	Med	Q	Med	Q	Med	Q	Med	Q	Med	Q	Med	Q
0	17	5.9	19.3	7.1	14.3	5.7	52.5	1.9	246	28.6	*	*	*	*	*	*	7	0.7
0.5	13	6.1	18.5	2.7	14.3	6.1	51	4	208	48	73	14	*	*	*	*	8	1
1	20	6.5	16.5	7.1	15.4	6.2	52.5	2.4	193	42.1	81	9.4	50.5	7.5	*	*	8	1
2	32	7.2	19.8	4.8	15.9	4.4	53	2.6	176	24.9	77	16	51	18.4	*	*	7	0.6
3	35	8.2	22.7	4.5	19.6	6	56	2	148	16.8	48	10	34	6.7	104	12	9	0.5
4	38	9.2	21.7	4.8	19.6	4.7	54.5	2.5	134	18.5	39	9.3	30	6	102	16.4	8.5	0.5
5	35	10.2	22.4	3.5	19.3	3.4	56	1.5	132	19.3	41	6	30	5	88	17.5	9	0.5
6	35	11.5	24.7	2.5	21.1	3.5	56	3	100	18.8	36	6.8	24	4.5	72	12	9	0.5
7	34	12.6	22	5.5	19.3	3.9	56	2.5	102	18.3	38	6.3	23.5	4.5	74.5	19.6	9	0.5
8	24	13.5	23.1	4.2	19.2	3.8	57.5	0.8	86	10.5	28	3.3	18.5	1.7	62	13	9	0

Data from Session I are reported. Short story: N of recalled elements (out of 34). *Attentional Matrices*: the number of crossed targets (*N*; max. 60) and time (s) to complete the test are reported. *Trail Making Test*: time values (s) are reported for the three parts, A, A/B and B. *Most children could not perform the task. *FAB*: overall score (max. 9). *Statistics*: *M*, mean; *SD*, standard deviation; *Med*, median; *Q*, semi-interquartile range. Non-parametric descriptive statistics (Median and Q) are reported for raw scores that are not normally distributed

Neuropsychological assessment

The overall testing time was about 20 min. The Short Story Test was administered first; selective attention abilities and frontal functions were assessed during the 15-min interval between the immediate and the delayed recalls of the Short Story Test.

Short Story Test

In order to limit verbal material learning effects from the 1st to the 2nd session, two different stories (1 and 2, see Appendix) were constructed. Eighty-five children recalled Story 1 on the first session and Story 2 on the second one; the order was reversed for the other 72 children. At variance with the standard procedure of administration of the Story Recall Test [20], we decided to introduce a second immediate recall. Thus, in each session, the examiner read the Short Story aloud, asked for immediate recall, read the Story aloud again, requesting immediate recall, administered other tests for 15 min, and finally asked for the delayed recall. We suggest in clinical practice to administer the attentional and executive tasks of this battery before the delayed recall to control for the effects of other forms of interferences.

Scoring. Each Story consisted of 34 morphological units.
The scoring criteria were the following:

– nouns were considered correctly recalled when their root was kept, irrespective of the flexion (e.g., *green* instead of *greenish*);
– synonyms were accepted as correct recalls (e.g. *cat/kitten*).

The average of the number of correctly recalled morphological units over 3 recall trials was the final score (total maximum score: 34).

Attentional Matrices

Three matrices of numbers were administered with the instruction to cross out as fast as possible target numbers of either one, two or three digits. The purpose of this test was to assess the subjects' ability to detect visual targets among distractors. The material used in this study was the same as that in Spinnler and Tognoni's study [21], but instructions were adapted for children and the task had no time limit. The overall number of targets that were crossed out divided by the number of seconds across the three matrices was the final score.

Trail Making Test (TMT)

This test explores different cognitive components, in particular attentional skills, visuo-motor planning, sustained attention and working memory. Subjects were presented with an A4 sheet with circles containing a number and requested to link, as fast as possible, all the circles, following their ascending numerical order. There are two TMT forms available [22]: the TMT A with only numbers (from 1 to 25), and the TMT B with alternating numbers and letters (from 1, A; 2, B; … to 13). We also introduced a new form 'A/B', to be administered between forms A and B, with only letters as stimuli (from A to Z). The instructions for this form were to link the letters in alphabetical order. This test was aimed at ensuring that children, especially the younger ones, had the alphabetical knowledge required to solve part B.

Frontal Assessment Battery (FAB)

To investigate mental flexibility, motor planning and executive control, we selected three out of six subtests from the FAB [23].

Motor planning and executive action control were explored by means of Luria's motor tasks. In the 'contrast' task, exploring the ability to prevent interference effects, subjects had to perform an action opposite to that performed by the examiner, refraining from the tendency to imitate the examiner's action. Inhibition of control was evaluated by a 'Go-No-Go' task.

Scores ranged from 0 (no correct responses) to 3 (all correct responses) for each subtest. The overall score was the sum of the three subtest scores (range: 0–9).

Statistical methods

Data analysis

Data were analysed by means of a general linear model (GLM) whenever the assumptions of normality and homoscedasticity were met. Raw data from the Short Story Test were normally and homoscedastically distributed, and those from the Attentional Matrices and Trail Making Subtests after logarithmic transformations (see Results for further details). Independent variables of the GLM were Age of Child, Age of Mother, Age of Father, Years of Education of the Child's Mother, Years of Education of the Child's Father, Gender (male *vs*. female) and Handedness (left-*vs*. right-hander). In the Short Story analysis one further variable was Story Form (Story 1 *vs*. Story 2).

The FAB data showed an irreducible ceiling effect so no transformation could normalise the distribution. Hence non-parametrics (Spearman's *r*) were applied to this data set.

Reliability indices were computed by means of Pearson's correlation between the adjusted scores when normality was satisfied (Short Story, Attentional Matrices, Trail Making); Spearman's *r* was used otherwise (FAB).

Diagnosis

For all the tests that allowed the application of a GLM (normality and homoscedasticity satisfied), adjustment tables were computed on grounds of a linear model including only the predictors yielding a significant effect in the GLM itself.

Adjusted scores were provided together with the rules for conversion to equivalent scores [24]. Equivalent scores range from 0 to 4, with children obtaining a score of 0 being diagnosed with a clear pathology, 1 borderline, 2 and 3 low–normal, and 4 superior (4 corresponds to scores above the mean of the standardisation sample). Equivalent scores correspond to specific z points; thus 0 corresponds to scores below z=–1.86 (3.1% of the standardisation sample); 1 to scores between z=–1.86 and z=–1.24 (7.6%); 2 to scores between –1.24 and –0.62 (16%); 3 to scores between –0.62 and 0 (23.2%); and 4 to scores above z=0 (50%).

Another diagnostic system was also provided, whenever adjustment procedures could be applied, according to the logic of "non-parametric tolerance limits" [25]. This system takes into account that the usual cut-offs for pathology, e.g., the 5th percentile, are estimates from a sample, and not the true values that would be obtained from the (infinite) population; thus, there is some uncertainty as to the real position of the cut-off. The "outer tolerance limit (OTL)" is a cut-off farther away from the mean than the usual one; the OTL guarantees (with 95% probability) that no more than 5% of the reference population score actually below it. The "inner tolerance limit (ITL)" is another cut-off, closer to the mean, that guarantees (again with 95% probability)

that no less than 5% of the reference population score below it. Therefore, a diagnosis of pathology is rather safe if the score is below the OTL, and a diagnosis of normality is also rather safe if the score is above the ITL. Uncertainty remains for individuals scoring in between. Quite naturally, three diagnostic categories follow: pathological (below OTL), "borderline" or "uncertain" (between OTL and ITL) and normal (above ITL). Clearly, for tests in which pathological scores are higher (not lower) than the mean (e.g., Trail Making Test), the OTL is above, not below, the ITL. Non-parametric tolerance limits were applied because adjusted scores were used to derive them [25]. Both outer and inner tolerance limits referred to the estimation of the 5th percentile and had a confidence level of 95%.

Results

Table 1 reports subjects' characteristics and descriptive statistics of the main raw test scores.

Short Story Test

The score distribution did not show ceiling or floor effects. Furthermore, the distribution was unimodal and symmetrical, thus allowing for standard parametrical statistical analyses. This regularity was confirmed after the application of the GLM: residuals distributed very closely to a Gaussian (skewness=0.064, SE=0.147; kurtosis=0.126, SE=0.294).

Variables inducing significant effects (GLM)

Overall scores obtained on the first session were considered as the reference distribution.

Variables that significantly influenced the subjects' scores were:

1. *Age of child.* Older children showed better memory abilities ($F(1, 268)=43.576$, $p<0.001$). The average performance increased by 0.77 elements per year of age.
2. *Years of education of the child's mother.* The child's memory performance increased by 0.28 elements/morphological units per year of mother's education ($F(1, 268)=5.918$, $p=0.016$).
3. *Years of education of the child's father.* The child's memory performance increased by 0.33 units per year of father's education ($F(1,268)=10.094$, $p=0.002$).
4. *Story form.* Story 1 was easier to recall than Story 2 ($F(1,268)=36.716$, $p<0.001$). The advantage was of about 3 units, with an average of 21.5 recalled from Story 1, and 18.5 recalled from Story 2.

Adjustment tables

Table 2 reports the adjustment values and the equivalent scores. The adjustment values have to be added to the child's raw 'overall' score as a function of age, father's education, mother's education and form of the Short Story Test (1 or 2) (Table 2).

Table 2 Adjustment values, equivalent scores and non-parametric tolerance limits for the Short Story Test; to be applied on the raw 'overall' score

Fye	Mye	Child's age (years)									
		5	6	7	8	9	10	11	12	13	14
5	5	–10.19	–10.95	–11.72	–12.49	–13.26	–14.03	–14.79	–15.56	–16.33	–17.1
5	8	–11.04	–11.81	–12.58	–13.34	–14.11	–14.88	–15.65	–16.42	–17.18	–17.95
5	13	–12.47	–13.23	–14	–14.77	–15.54	–16.31	–17.07	–17.84	–18.61	–19.38
5	17	–13.61	–14.37	–15.14	–15.91	–16.68	–17.45	–18.21	–18.98	–19.75	–20.52
8	5	–11.19	–11.96	–12.73	–13.49	–14.26	–15.03	–15.8	–16.57	–17.33	–18.1
8	8	–12.05	–12.81	–13.58	–14.35	–15.12	–15.89	–16.65	–17.42	–18.19	–18.96
8	13	–13.47	–14.24	–15.01	–15.77	–16.54	–17.31	–18.08	–18.85	–19.61	–20.38
8	17	–14.61	–15.38	–16.15	–16.91	–17.68	–18.45	–19.22	–19.99	–20.75	–21.52
13	5	–12.87	–13.63	–14.4	–15.17	–15.94	–16.71	–17.47	–18.24	–19.01	–19.78
13	8	–13.72	–14.49	–15.26	–16.02	–16.79	–17.56	–18.33	–19.1	–19.86	–20.63
13	13	–15.15	–15.91	–16.68	–17.45	–18.22	–18.99	–19.75	–20.52	–21.29	–22.06
13	17	–16.29	–17.05	–17.82	–18.59	–19.36	–20.13	–20.89	–21.66	–22.43	–23.2
17	5	–14.21	–14.97	–15.74	–16.51	–17.28	–18.05	–18.81	–19.58	–20.35	–21.12
17	8	–15.06	–15.83	–16.6	–17.36	–18.13	–18.9	–19.67	–20.44	–21.2	–21.97
17	13	–16.49	–17.25	–18.02	–18.79	–19.56	–20.33	–21.09	–21.86	–22.63	–23.4
17	17	–17.63	–18.39	–19.16	–19.93	–20.7	–21.47	–22.23	–23	–23.77	–24.54

Fye, father's years of education; *Mye*, mother's years of education

→

Adjusted score	Equivalent score
Below –8.42	0
From –8.42 to –5.62	1
From –5.62 to –2.81	2
From –2.81 to 0	3
Above 0	4

Non-parametric tolerance limits for the 5th percentile (level of confidence: 95%)

Adjusted score	Diagnosis
Below –8.95 (OTL)	Pathological
From –8.95 (OTL) to –6.93 (ITL)	Uncertain
Above –6.93 (ITL)	Normal

IMPORTANT: If Story 1 was administered, beyond applying the adjustment parameters of Table 2, subtract another 3.337 points. For instance, the Adjusted score of a 9-year-old child who was administered Story 1, whose father has 5 years of education, whose mother has 8 years of education, and who obtained a raw score of 10, is 10–14.11–3.337=–7.447 (Equivalent score 1)

Reliability

A test–retest reliability index was computed by obtaining Pearson's linear correlation coefficient between the (adjusted) scores on the first and second session (n=154). The obtained estimate was r=0.676.

Attentional Matrices

While adults generally perform the Attentional Matrices with high accuracy (about 100% targets detected) and vary only in the time employed to complete the search task, children can show considerable variability in accuracy. Therefore, we introduced a measure which takes into account both time and accuracy.

This measure is the average frequency of detection (number of targets per second), i.e., the overall number of detected targets (N) divided by overall time in seconds (t). One of the advantages of this measure is that it does not show ceiling or floor effects. It also allows for parametric statistics and simple linear model analyses after a logarithmic transformation. The final score was thus the natural logarithm of the average frequency: ln(N/t).

The suitability of the GLM model was confirmed by the analysis of the distribution of the GLM residuals, which was very close to Gaussian (skewness=0.139, kurtosis=-0.29).

Variables inducing significant effects (GLM)

Variables that significantly influenced the subjects' M scores were: *age of child* (F(1,280)=559.982, p<0.001) and *gender* (F(1,280)=9.838, p=0.002).

Adjustment table

Because of the logarithmic transformation, the adjustment of scores cannot be made directly. Table 3 shows the equivalent scores as a function of frequency scores (N/t), age and gender of the child to be assessed. To use the table, one has to select the row reporting gender and age of the assessed child (male: first 10 rows; female: last 10 rows). In each row, the ranges of N/t scores corresponding to equivalent scores are reported.

For example, a 9-year-old girl who detected 49 targets in 162 seconds has a N/t=49/162=0.302. By scanning the row (F, 9), 0.302 is found in the range 0.29–0.33, which corresponds to an equivalent score of 2 and to a "normality" diagnosis according to the Tolerance Limits criterion (Table 3).

Reliability

The test–retest reliability index, computed on 157 subjects was r=0.825. Performance neither improved nor worsened at retest.

Trail Making Test (TMT)

It was quite evident that some conditions of this test are not adequate for children, particularly for those who have not yet acquired enough numerical and alphabetical knowledge to perform the task. For instance, children at the beginning of the 1st school year could not successfully complete TMT part A; some children who were tested in the middle of their 1st primary school year were not able to complete TMT part A/B; TMT part B was successfully performed only by children of the 3rd primary school year or older.

Therefore, TMT part A is suitable for children who have already attended the first half of the 1st school year; TMT part A/B for subjects who have already finished the 1st school year; TMT part B for children who have finished the 2nd school year. Subjects who did not meet these criteria were excluded from further statistical analyses.

TMT part A

We used the measure T=ln(sec/100), i.e., the natural logarithm of the overall time, in seconds, divided by 100. This measure allowed us to use parametric statistics because it stabilised the score variance across different levels of performance. The distribution of residuals was very close to Gaussian (kurtosis=0.458, skewness=-0.026).

Overall time varied from 15 to 215 s in the sample. The statistical analysis showed a significant learning effect, i.e., a significant improvement from session 1 (53 s on average) to session 2 (43 s) (F(1,128)=36.04, p<0.001).

Table 3 Attentional Matrices. Ranges of *N/t* values corresponding to different equivalent scores (0–4) and to different diagnoses according to the non-parametric tolerance limits criteria

		Equivalent scores								Non-parametric tolerance limits		
		0	1		2		3		4	Pathological	Uncertain	Normal
Gender	Age	Below	From	To	From	To	From	To	Above	Below	From–to	Above
M	5	0.13	0.13	0.15	0.15	0.18	0.18	0.21	0.21	0.13	0.13–0.14	0.14
	6	0.15	0.15	0.18	0.18	0.20	0.20	0.23	0.23	0.15	0.15–0.16	0.16
	7	0.17	0.17	0.20	0.20	0.23	0.23	0.27	0.27	0.17	0.17–0.19	0.19
	8	0.20	0.20	0.23	0.23	0.26	0.26	0.31	0.31	0.19	0.19–0.21	0.21
	9	0.23	0.23	0.26	0.26	0.30	0.30	0.35	0.35	0.22	0.22–0.24	0.24
	10	0.26	0.26	0.30	0.30	0.35	0.35	0.40	0.40	0.25	0.25–0.28	0.28
	11	0.30	0.30	0.34	0.34	0.39	0.39	0.46	0.46	0.29	0.29–0.32	0.32
	12	0.34	0.34	0.39	0.39	0.45	0.45	0.52	0.52	0.33	0.33–0.36	0.36
	13	0.39	0.39	0.45	0.45	0.52	0.52	0.59	0.59	0.38	0.38–0.42	0.42
	14	0.44	0.44	0.51	0.51	0.59	0.59	0.68	0.68	0.43	0.43–0.48	0.48
F	5	0.15	0.15	0.17	0.17	0.19	0.19	0.22	0.22	0.14	0.14–0.16	0.16
	6	0.17	0.17	0.19	0.19	0.22	0.22	0.26	0.26	0.16	0.16–0.18	0.18
	7	0.19	0.19	0.22	0.22	0.25	0.25	0.29	0.29	0.19	0.19–0.20	0.20
	8	0.22	0.22	0.25	0.25	0.29	0.29	0.33	0.33	0.21	0.21–0.23	0.23
	9	0.25	0.25	0.29	0.29	0.33	0.33	0.38	0.38	0.24	0.24–0.27	0.27
	10	0.28	0.28	0.33	0.33	0.38	0.38	0.43	0.43	0.28	0.28–0.30	0.30
	11	0.32	0.32	0.37	0.37	0.43	0.43	0.50	0.50	0.32	0.32–0.35	0.35
	12	0.37	0.37	0.43	0.43	0.49	0.49	0.57	0.57	0.36	0.36–0.40	0.40
	13	0.42	0.42	0.49	0.49	0.56	0.56	0.65	0.65	0.41	0.41–0.45	0.45
	14	0.48	0.48	0.56	0.56	0.64	0.64	0.74	0.74	0.47	0.47–0.52	0.52

Variables inducing significant effects (GLM)

Child's age ($F(1,254)=263.573$, $p<0.001$). The older, the faster. This advantage was 2 s per year for fast subjects (overall time around 18 s) and 30 s per year for slow subjects (overall time around 220 s).

Father's education ($F(1,254)=5.917$, $p=0.016$). The higher the fathers' education, the better the children's performance. The difference between a child whose father graduated from university (education=17 years) and a child whose father completed primary school (education=5 years) ranged between 2 s (very fast children) and 30 s (very slow children).

Adjustment table

These two variables were used to obtain equivalent scores. Due to the logarithmic transformation, the computation of adjusted scores would be quite complex from a mathematical viewpoint. Table 4 indicates the equivalent scores as a function of demographic characteristics and overall time to perform the task.

For example, in the case of an 11-year-old boy whose father completed primary school education (5 years) and who took 74 s to complete TMT part A, it is necessary to find the row matching the child's age and father's education and then intersect the column showing the range of values where the child's overall time falls. In this case, the range 64.6–78.6 corresponds to an equivalent score of 1. As for the Tolerance Limits criterion, an "uncertain", or borderline diagnosis will hold (Table 4).

Reliability

The estimated correlation coefficient was $r=0.772$, obtained on 140 subjects.

TMT part A/B

The residuals' distribution was satisfactorily close to Gaussian (skewness=-0.593, kurtosis=1.264). We found a learning effect between test and retest ($F(1,122)=29.427$, $p<0.001$).

Variables inducing significant effects (GLM)

The same variables affecting scores in TMT part A, i.e., *age* and *father's education*, significantly influenced the scores in TMT part A/B too.

Adjustment table

Table 5 shows equivalent scores obtained with the same procedure as in TMT part A.

Reliability

The estimated correlation coefficient was $r=0.685$, obtained on 134 subjects.

Table 4 Trail Making Test (part A). Equivalent scores and non-parametric tolerance limits diagnoses as a function of demographic characteristics and overall time (s) to perform the task

		Equivalent scores								Non-parametric tolerance limits			
		4	3		2		1		0	Normal	Uncertain		Pathological
Age	Father's education	Shorter than	From	To	From	To	From	To	Longer than	Shorter than	From	To	Longer than
6	5	89.7	89.7	109.1	109.1	132.7	132.7	161.5	161.5	140.2	140.2	157.0	157.0
6	8	85.8	85.8	104.4	104.4	127.0	127.0	154.5	154.5	134.1	134.1	150.1	150.1
6	13	79.7	79.7	96.9	96.9	117.9	117.9	143.4	143.4	124.6	124.6	139.4	139.4
6	17	75.1	75.1	91.3	91.3	111.1	111.1	135.2	135.2	117.4	117.4	131.4	131.4
7	5	77.6	77.6	94.5	94.5	114.9	114.9	139.8	139.8	121.4	121.4	135.9	135.9
7	8	74.3	74.3	90.4	90.4	109.9	109.9	133.7	133.7	116.1	116.1	130.0	130.0
7	13	69.0	69.0	83.9	83.9	102.1	102.1	124.2	124.2	107.9	107.9	120.7	120.7
7	17	65.0	65.0	79.1	79.1	96.2	96.2	117.1	117.1	101.7	101.7	113.8	113.8
8	5	67.2	67.2	81.8	81.8	99.5	99.5	121.1	121.1	105.1	105.1	117.7	117.7
8	8	64.3	64.3	78.2	78.2	95.2	95.2	115.8	115.8	100.6	100.6	112.6	112.6
8	13	59.7	59.7	72.7	72.7	88.4	88.4	107.5	107.5	93.4	93.4	104.5	104.5
8	17	56.3	56.3	68.5	68.5	83.3	83.3	101.4	101.4	88.0	88.0	98.5	98.5
9	5	58.2	58.2	70.8	70.8	86.2	86.2	104.8	104.8	91.0	91.0	101.9	101.9
9	8	55.7	55.7	67.8	67.8	82.4	82.4	100.3	100.3	87.1	87.1	97.5	97.5
9	13	51.7	51.7	62.9	62.9	76.5	76.5	93.1	93.1	80.9	80.9	90.5	90.5
9	17	48.7	48.7	59.3	59.3	72.1	72.1	87.8	87.8	76.2	76.2	85.3	85.3
10	5	50.4	50.4	61.3	61.3	74.6	74.6	90.8	90.8	78.8	78.8	88.2	88.2
10	8	48.2	48.2	58.7	58.7	71.4	71.4	86.8	86.8	75.4	75.4	84.4	84.4
10	13	44.8	44.8	54.5	54.5	66.3	66.3	80.6	80.6	70.0	70.0	78.4	78.4
10	17	42.2	42.2	51.3	51.3	62.5	62.5	76.0	76.0	66.0	66.0	73.9	73.9
11	5	43.6	43.6	53.1	53.1	64.6	64.6	78.6	78.6	68.3	68.3	76.4	76.4
11	8	41.8	41.8	50.8	50.8	61.8	61.8	75.2	75.2	65.3	65.3	73.1	73.1
11	13	38.8	38.8	47.2	47.2	57.4	57.4	69.8	69.8	60.6	60.6	67.9	67.9
11	17	36.5	36.5	44.5	44.5	54.1	54.1	65.8	65.8	57.1	57.1	64.0	64.0
12	5	37.8	37.8	46.0	46.0	55.9	55.9	68.1	68.1	59.1	59.1	66.2	66.2
12	8	36.2	36.2	44.0	44.0	53.5	53.5	65.1	65.1	56.5	56.5	63.3	63.3
12	13	33.6	33.6	40.8	40.8	49.7	49.7	60.5	60.5	52.5	52.5	58.8	58.8
12	17	31.6	31.6	38.5	38.5	46.8	46.8	57.0	57.0	49.5	49.5	55.4	55.4
13	5	32.7	32.7	39.8	39.8	48.4	48.4	58.9	58.9	51.2	51.2	57.3	57.3
13	8	31.3	31.3	38.1	38.1	46.3	46.3	56.4	56.4	49.0	49.0	54.8	54.8
13	13	29.1	29.1	35.4	35.4	43.0	43.0	52.4	52.4	45.5	45.5	50.9	50.9
13	17	27.4	27.4	33.3	33.3	40.6	40.6	49.3	49.3	42.8	42.8	48.0	48.0
14	5	28.3	28.3	34.5	34.5	41.9	41.9	51.0	51.0	44.3	44.3	49.6	49.6
14	8	27.1	27.1	33.0	33.0	40.1	40.1	48.8	48.8	42.4	42.4	47.4	47.4
14	13	25.2	25.2	30.6	30.6	37.3	37.3	45.3	45.3	39.4	39.4	44.1	44.1
14	17	23.7	23.7	28.9	28.9	35.1	35.1	42.7	42.7	37.1	37.1	41.5	41.5

Table 5 Trail Making Test (part A/B). Equivalent scores and non-parametric tolerance limits diagnoses as a function of demographic characteristics and overall time (s) to perform the task

		Equivalent scores								Non-parametric tolerance limits			
		4	3		2		1		0	Normal	Uncertain		Pathological
Age	Father's education	Shorter than	From	To	From	To	From	To	Longer than	Shorter	From	To	Longer than
6	5	59.9	59.9	73.7	73.7	90.6	90.6	111.4	111.4	108.5	108.5	131.9	131.9
6	8	58.2	58.2	71.6	71.6	88.0	88.0	108.2	108.2	105.4	105.4	128.1	128.1
6	13	55.4	55.4	68.1	68.1	83.8	83.8	103.0	103.0	100.4	100.4	122.0	122.0
6	17	53.3	53.3	65.5	65.5	80.5	80.5	99.0	99.0	96.5	96.5	117.3	117.3
7	5	51.6	51.6	63.4	63.4	78.0	78.0	95.9	95.9	93.4	93.4	113.6	113.6
7	8	50.1	50.1	61.6	61.6	75.7	75.7	93.1	93.1	90.7	90.7	110.3	110.3
7	13	47.7	47.7	58.6	58.6	72.1	72.1	88.6	88.6	86.4	86.4	105.0	105.0
7	17	45.9	45.9	56.4	56.4	69.3	69.3	85.2	85.2	83.1	83.1	101.0	101.0
8	5	44.4	44.4	54.6	54.6	67.1	67.1	82.5	82.5	80.4	80.4	97.7	97.7
8	8	43.1	43.1	53.0	53.0	65.2	65.2	80.1	80.1	78.1	78.1	94.9	94.9
8	13	41.1	41.1	50.5	50.5	62.1	62.1	76.3	76.3	74.4	74.4	90.4	90.4
8	17	39.5	39.5	48.5	48.5	59.7	59.7	73.4	73.4	71.5	71.5	86.9	86.9
9	5	38.2	38.2	47.0	47.0	57.8	57.8	71.0	71.0	69.2	69.2	84.1	84.1
9	8	37.1	37.1	45.6	45.6	56.1	56.1	69.0	69.0	67.2	67.2	81.7	81.7
9	13	35.3	35.3	43.4	43.4	53.4	53.4	65.7	65.7	64.0	64.0	77.8	77.8
9	17	34.0	34.0	41.8	41.8	51.4	51.4	63.1	63.1	61.5	61.5	74.8	74.8
10	5	32.9	32.9	40.4	40.4	49.7	49.7	61.1	61.1	59.6	59.6	72.4	72.4
10	8	31.9	31.9	39.3	39.3	48.3	48.3	59.4	59.4	57.8	57.8	70.3	70.3
10	13	30.4	30.4	37.4	37.4	46.0	46.0	56.5	56.5	55.1	55.1	67.0	67.0
10	17	29.2	29.2	36.0	36.0	44.2	44.2	54.3	54.3	53.0	53.0	64.4	64.4
11	5	28.3	28.3	34.8	34.8	42.8	42.8	52.6	52.6	51.3	51.3	62.3	62.3
11	8	27.5	27.5	33.8	33.8	41.6	41.6	51.1	51.1	49.8	49.8	60.5	60.5
11	13	26.2	26.2	32.2	32.2	39.6	39.6	48.6	48.6	47.4	47.4	57.6	57.6
11	17	25.2	25.2	30.9	30.9	38.0	38.0	46.8	46.8	45.6	45.6	55.4	55.4
12	5	24.4	24.4	30.0	30.0	36.8	36.8	45.3	45.3	44.1	44.1	53.6	53.6
12	8	23.7	23.7	29.1	29.1	35.8	35.8	44.0	44.0	42.9	42.9	52.1	52.1
12	13	22.5	22.5	27.7	27.7	34.1	34.1	41.9	41.9	40.8	40.8	49.6	49.6
12	17	21.7	21.7	26.6	26.6	32.7	32.7	40.3	40.3	39.2	39.2	47.7	47.7
13	5	21.0	21.0	25.8	25.8	31.7	31.7	39.0	39.0	38.0	38.0	46.2	46.2
13	8	20.4	20.4	25.0	25.0	30.8	30.8	37.8	37.8	36.9	36.9	44.8	44.8
13	13	19.4	19.4	23.8	23.8	29.3	29.3	36.0	36.0	35.1	35.1	42.7	42.7
13	17	18.6	18.6	22.9	22.9	28.2	28.2	34.7	34.7	33.8	33.8	41.1	41.1
14	5	18.1	18.1	22.2	22.2	27.3	27.3	33.5	33.5	32.7	32.7	39.7	39.7
14	8	17.5	17.5	21.6	21.6	26.5	26.5	32.6	32.6	31.7	31.7	38.6	38.6
14	13	16.7	16.7	20.5	20.5	25.2	25.2	31.0	31.0	30.2	30.2	36.7	36.7
14	17	16.1	16.1	19.7	19.7	24.3	24.3	29.8	29.8	29.1	29.1	35.3	35.3

TMT part B

The residuals' distribution was very close to Gaussian (skewness=-0.112; kurtosis=0.128). TMT part B seems to involve different cognitive processes from those involved in TMT parts A and A/B. Pearson's correlation between TMT part A and part A/B was high (about 0.7); the correlations between A and B on the one hand, and between A/B and B on the other, were much smaller (about 0.4).

Pearson's correlation coefficients between TMT parts A, A/B and B were the following: A/B *vs*. A=0.699 (n=263), B *vs*. A=0.421 (n=190) and B *vs*. A/B=0.419 (n=190).

By analysing TMT part B data, a clear learning effect was found between test and retest ($F(1,95)=25.708$, $p<0.001$): subjects became about 9 s faster in session 2.

Variables inducing significant effects (GLM)

The GLM analysis on the first session data showed effects of *age* ($F(1,188)=23.205$, $p<.001$), *mother's education* ($F(1,188)=5.84$, $p=0.017$), *gender* ($F(1,188)=3.991$, $p=0.047$), the interaction *gender* with *handedness* ($F(1,188)=8.955$, $p=0.003$) and the interaction *gender* with *handedness* with *age* ($F(3,188)=3.84$, $p=0.011$).

Adjustment tables

For the purpose of score adjustment, all variables producing significant effects and complex interactions were taken into account. Table 6a reports data on children aged 8–10 years, who showed also a handedness effect (interacting with gender). Table 6b reports data on children aged 11–14, who did not show the above interaction.

Reliability

The TMT part B reliability index was lower than that of parts A and A/B: $r=0.613$, estimated on 107 subjects.

FAB

The overall scores obtained from the three selected subtests (range: 0–9) were distributed in a strongly asymmetrical way (skewness=-1.874; kurtosis=4.619) due to a clear ceiling effect. Therefore, no adjustment procedure could be applied and non-parametric statistics were used.

There was a small (0.31 points on average) but significant learning effect (Wilcoxon: $z=3.498$, $p<0.001$).

Variable inducing significant effects

The only significant effect was the *child's age* (Spearman's $r=0.377$, $p<0.001$), calculated on 283 children.

Adjustment table

Although the FAB score distribution is not Gaussian, equivalent scores having similar meaning as the 'classical' ones [21] could be obtained. Thus, for a given FAB score, the percentage of subjects of the normative sample who obtained lower scores was taken, and the equivalent score corresponding to that percentage was assigned to that particular case. Table 7 reports equivalent scores as a function of raw FAB scores and child's age.

Reliability

The non-parametric correlation coefficient was not very high: Spearman's $r=0.389$, obtained from 157 subjects.

Discussion

In this study tests assessing long-term episodic verbal memory (the Short Story Test), attention (Attentional Matrices, the Trail Making Test A, A/B and B) and frontal functions (FAB) have been standardised on an Italian sample of 283 normally developing subjects aged 5–14.

In the Short Story Test the verbal content seems to be consolidated in the long-term memory store by the second recall. The administration of non-verbal tasks between this recall and the third delayed recall does not seem to affect the mnemonic trace of the verbal material. The number of recalled elements increases progressively with age.

Considering the long-term verbal memory performance, we observed that the recall pattern changes in the sample of 6–8-year-olds, suggesting the involvement of new cognitive strategies at this stage. Different theories on the mnemonic strategies applied by children during development have been elaborated so far: the first systematic studies began around 1960 [26], with a renewed interest in Piaget's [27] and Bruner et al.'s investigations [28]. Flavell et al. developed the learning theory concept applied to verbal rehearsal as a function of age [29]. Further investigations pointed out the importance of grouping strategies in memory functioning: some authors speculated that they are active only starting from the age of 10–11 years [30, 31], while others found that grouping processes can be applied earlier, even if children are not aware of them [32]. The awareness of adopting memory strategies represents a relevant factor in the debate on the development of cognitive processes; it can also explain some of the literature's different results [33]. We propose that the changes in the recall pattern observed in our sub-sample of children aged 6–8 years might be ascribed to the development of new strategies of control, selection and re-arrangement of information, particularly required for structural contents, which can be active also at this age [5, 34].

A significant performance variability (i.e., the global number of correct targets) has been observed at the Attentional Matrices, in contrast with what is noticed in adults, who mainly vary in the task execution time. Children's performance at the Attentional Matrices probably depends on a lack of efficiency of the filter process, which prevents the encoding of irrelevant information,

Table 6a Trail Making Test (part B). Children aged 8–10 years. Equivalent scores and non-parametric tolerance limits diagnoses as a function of demographic characteristics and overall time (s) to perform the task

			Equivalent scores								Non-parametric tolerance limits			
			4	3		2		1		0	Normal	Uncertain		Pathological
Child's age	Mother's education	Gender/ Handedness	Shorter than	From	To	From	To	From	To	Longer than	Shorter than	From	To	Longer than
8	5	R	123.7	123.7	145.4	145.4	171.0	171.0	201.1	201.1	179.3	179.3	215.3	215.3
8	5	LM	99.5	99.5	117.1	117.1	137.7	137.7	161.9	161.9	144.3	144.3	173.3	173.3
8	5	LF	164.8	164.8	193.8	193.8	227.9	227.9	268.0	268.0	238.9	238.9	286.9	286.9
8	8	R	116.1	116.1	136.5	136.5	160.6	160.6	188.8	188.8	168.3	168.3	202.1	202.1
8	8	LM	93.5	93.5	109.9	109.9	129.3	129.3	152.0	152.0	135.5	135.5	162.7	162.7
8	8	LF	154.7	154.7	181.9	181.9	214.0	214.0	251.6	251.6	224.3	224.3	269.3	269.3
8	13	R	104.5	104.5	122.9	122.9	144.6	144.6	170.0	170.0	151.5	151.5	182.0	182.0
8	13	LM	84.1	84.1	99.0	99.0	116.4	116.4	136.8	136.8	122.0	122.0	146.5	146.5
8	13	LF	139.3	139.3	163.8	163.8	192.6	192.6	226.5	226.5	201.9	201.9	242.5	242.5
8	17	R	96.1	96.1	113.0	113.0	132.9	132.9	156.3	156.3	139.3	139.3	167.3	167.3
8	17	LM	77.4	77.4	91.0	91.0	107.0	107.0	125.8	125.8	112.2	112.2	134.7	134.7
8	17	LF	128.1	128.1	150.6	150.6	177.1	177.1	208.3	208.3	185.7	185.7	223.0	223.0
9	5	R	117.0	117.0	137.6	137.6	161.8	161.8	190.3	190.3	169.6	169.6	203.7	203.7
9	5	LM	94.2	94.2	110.8	110.8	130.3	130.3	153.2	153.2	136.5	136.5	164.0	164.0
9	5	LF	155.9	155.9	183.4	183.4	215.6	215.6	253.6	253.6	226.0	226.0	271.5	271.5
9	8	R	109.9	109.9	129.2	129.2	152.0	152.0	178.7	178.7	159.3	159.3	191.3	191.3
9	8	LM	88.4	88.4	104.0	104.0	122.3	122.3	143.8	143.8	128.2	128.2	154.0	154.0
9	8	LF	146.4	146.4	172.2	172.2	202.5	202.5	238.1	238.1	212.2	212.2	254.9	254.9
9	13	R	98.9	98.9	116.3	116.3	136.8	136.8	160.9	160.9	143.4	143.4	172.2	172.2
9	13	LM	79.6	79.6	93.6	93.6	110.1	110.1	129.5	129.5	115.4	115.4	138.6	138.6
9	13	LF	131.8	131.8	155.0	155.0	182.3	182.3	214.4	214.4	191.1	191.1	229.5	229.5
9	17	R	91.0	91.0	107.0	107.0	125.8	125.8	147.9	147.9	131.9	131.9	158.3	158.3
9	17	LM	73.2	73.2	86.1	86.1	101.2	101.2	119.1	119.1	106.1	106.1	127.5	127.5
9	17	LF	121.2	121.2	142.5	142.5	167.6	167.6	197.1	197.1	175.7	175.7	211.0	211.0
10	5	R	110.7	110.7	130.2	130.2	153.1	153.1	180.1	180.1	160.5	160.5	192.8	192.8
10	5	LM	89.1	89.1	104.8	104.8	123.3	123.3	145.0	145.0	129.2	129.2	155.2	155.2
10	5	LF	147.6	147.6	173.5	173.5	204.1	204.1	240.0	240.0	213.9	213.9	256.9	256.9
10	8	R	104.0	104.0	122.3	122.3	143.8	143.8	169.1	169.1	150.7	150.7	181.0	181.0
10	8	LM	83.7	83.7	98.4	98.4	115.7	115.7	136.1	136.1	121.3	121.3	145.7	145.7
10	8	LF	138.5	138.5	162.9	162.9	191.6	191.6	225.3	225.3	200.8	200.8	241.2	241.2
10	13	R	93.6	93.6	110.1	110.1	129.5	129.5	152.2	152.2	135.7	135.7	163.0	163.0
10	13	LM	75.4	75.4	88.6	88.6	104.2	104.2	122.5	122.5	109.2	109.2	131.2	131.2
10	13	LF	124.7	124.7	146.7	146.7	172.5	172.5	202.9	202.9	180.8	180.8	217.2	217.2
10	17	R	86.1	86.1	101.2	101.2	119.0	119.0	140.0	140.0	124.8	124.8	149.8	149.8
10	17	LM	69.3	69.3	81.5	81.5	95.8	95.8	112.7	112.7	100.4	100.4	120.6	120.6
10	17	LF	114.7	114.7	134.9	134.9	158.6	158.6	186.5	186.5	166.2	166.2	199.7	199.7

R, right-handed; *LF*, left-handed, female; *LM*, left-handed, male

Table 6b Trail Making Test (part B). Children aged 11–14 years. Equivalent scores and non-parametric tolerance limits diagnoses as a function of demographic characteristics and overall time (s) to perform the task

			Equivalent scores								Non-parametric tolerance limits			
			4	3		2		1		0	Normal	Uncertain		Pathological
Child's age	Mother's education	Gender Handedness	Shorter than	From	To	From	To	From	To	Longer than	Shorter than	From	To	Longer than
11	5	M	88.2	88.2	104.8	104.8	124.6	124.6	148.1	148.1	127.8	127.8	153.5	153.5
11	5	F	77.4	77.4	92.0	92.0	109.4	109.4	130.1	130.1	112.2	112.2	134.8	134.8
11	8	M	84.4	84.4	100.4	100.4	119.3	119.3	141.9	141.9	122.4	122.4	147.0	147.0
11	8	F	74.1	74.1	88.1	88.1	104.8	104.8	124.6	124.6	107.5	107.5	129.1	129.1
11	13	M	78.6	78.6	93.4	93.4	111.0	111.0	132.0	132.0	113.9	113.9	136.8	136.8
11	13	F	69.0	69.0	82.0	82.0	97.5	97.5	115.9	115.9	100.0	100.0	120.1	120.1
11	17	M	74.2	74.2	88.2	88.2	104.8	104.8	124.6	124.6	107.5	107.5	129.1	129.1
11	17	F	65.1	65.1	77.4	77.4	92.0	92.0	109.4	109.4	94.4	94.4	113.4	113.4
12	5	M	83.5	83.5	99.3	99.3	118.0	118.0	140.3	140.3	121.1	121.1	145.4	145.4
12	5	F	73.3	73.3	87.2	87.2	103.6	103.6	123.2	123.2	106.3	106.3	127.7	127.7
12	8	M	80.0	80.0	95.1	95.1	113.0	113.0	134.4	134.4	115.9	115.9	139.2	139.2
12	8	F	70.2	70.2	83.5	83.5	99.3	99.3	118.0	118.0	101.8	101.8	122.3	122.3
12	13	M	74.4	74.4	88.5	88.5	105.2	105.2	125.0	125.0	107.9	107.9	129.6	129.6
12	13	F	65.4	65.4	77.7	77.7	92.4	92.4	109.8	109.8	94.7	94.7	113.8	113.8
12	17	M	70.3	70.3	83.5	83.5	99.3	99.3	118.0	118.0	101.8	101.8	122.3	122.3
12	17	F	61.7	61.7	73.3	73.3	87.2	87.2	103.7	103.7	89.4	89.4	107.4	107.4
13	5	M	79.1	79.1	94.1	94.1	111.8	111.8	132.9	132.9	114.7	114.7	137.7	137.7
13	5	F	69.5	69.5	82.6	82.6	98.2	98.2	116.7	116.7	100.7	100.7	120.9	120.9
13	8	M	75.8	75.8	90.1	90.1	107.1	107.1	127.3	127.3	109.8	109.8	131.9	131.9
13	8	F	66.5	66.5	79.1	79.1	94.0	94.0	111.8	111.8	96.4	96.4	115.8	115.8
13	13	M	70.5	70.5	83.8	83.8	99.6	99.6	118.5	118.5	102.2	102.2	122.7	122.7
13	13	F	61.9	61.9	73.6	73.6	87.5	87.5	104.0	104.0	89.7	89.7	107.8	107.8
13	17	M	66.6	66.6	79.1	79.1	94.1	94.1	111.8	111.8	96.5	96.5	115.9	115.9
13	17	F	58.4	58.4	69.5	69.5	82.6	82.6	98.2	98.2	84.7	84.7	101.7	101.7
14	5	M	74.9	74.9	89.1	89.1	105.9	105.9	125.9	125.9	108.6	108.6	130.5	130.5
14	5	F	65.8	65.8	78.2	78.2	93.0	93.0	110.6	110.6	95.4	95.4	114.6	114.6
14	8	M	71.8	71.8	85.3	85.3	101.4	101.4	120.6	120.6	104.0	104.0	125.0	125.0
14	8	F	63.0	63.0	74.9	74.9	89.1	89.1	105.9	105.9	91.4	91.4	109.7	109.7
14	13	M	66.8	66.8	79.4	79.4	94.4	94.4	112.2	112.2	96.8	96.8	116.3	116.3
14	13	F	58.6	58.6	69.7	69.7	82.9	82.9	98.5	98.5	85.0	85.0	102.1	102.1
14	17	M	63.1	63.1	75.0	75.0	89.1	89.1	105.9	105.9	91.4	91.4	109.8	109.8
14	17	F	55.4	55.4	65.8	65.8	78.3	78.3	93.0	93.0	80.3	80.3	96.4	96.4

Table 7 Equivalent scores as a function of FAB raw score and child's age

FAB raw score	Child's age								
	6	7	8	9	10	11	12	13	14
0–4	0	0	0	0	0	0	0	0	0
5	1	0	0	0	0	0	0	0	0
6	2	1	0	0	0	0	0	0	0
7	2	2	2	0	1	0	0	0	0
8	4	4	2	2	2	1	1	2	1
9	4	4	3	4	3	3	3	3	2

allowing subjects to filter out potential distractors [35]. Attentional tasks also involve a shifting component, which is a typical executive function monitored by the prefrontal cortex, although the performance improvement at this task may also be due to a higher visual searching ability related to the progressive development of the Frontal Eye Fields [36].

Regarding the Trail Making Test, we believe that parts A, A/B and B involve different cognitive systems. TMT part A and part A/B, in fact, involve the visual search and the activation of automatic series knowledge, with a minimal load on working memory (i.e., just the number/letter to be found next need be kept in the short-term memory store). TMT part B, on the contrary, requires the generation of a complex sequence (far from automatic in children) from the letter and number series, thus producing a massively high processing load on working memory and executive functions. Therefore, TMT part B involves a working memory component to a greater extent than parts A and A/B, the latter ones reflecting only the characteristics of visual search and general attentional systems.

A stepwise performance progression has been observed at the FAB, in particular in 7- and 8-year-old children, as after this stage children tend to reach 100% correct performance. This trend, showing that control processes gradually consolidate, seems to be related to the anatomical development of the frontal cortex, which is known to occur in this period [37].

We found that parents' education significantly influences children's performance on the Story Test and Trail Making Test, but does not affect the FAB. We believe that this result depends on the fact that the first two tests involve verbal material. Thus, one may speculate that a richer cultural environment plays an important role in modulating children's performance. On the contrary, procedural and motor components that are involved in the FAB are not influenced by cultural effects.

It may be objected that our test/retest reliability index seems lower than that usually reported in the literature. However, the reliability index is generally calculated on the raw scores. This procedure overestimates the correlation index because it does not take into account spurious correlation due to concomitant variables. In our analysis, the index has been calculated on scores that have been adjusted for those variables (age, father's education, mother's education), thus reflecting the real test–retest correlation. Furthermore, the correlation index for the Short Story Test has been calculated between two parallel forms. As a consequence, it is not surprising that our reliability indices are lower than those reported in the literature. Memory, attention and frontal functions are frequently impaired in children with epilepsy [38–43]. These cognitive dysfunctions have to be related to the various risk factors associated with epilepsy, such as type, duration, frequency of seizures, type of drug therapy, transient and chronic electrophysiological activity, and the possible anatomo-pathological correlates [44–51].

Amongst the several factors inducing learning impairment in patients with epilepsy, the "temporal gate hypothesis" [52] seems to provide a clear neurophysiopathological substrate for the typical cognitive dysfunctions found in children with epilepsy. The normal development of frontal lobe functions requires intact temporo-limbic connections and temporal lobe epilepsy in childhood may disrupt temporo-limbic input to frontal lobes inducing, as a consequence, an incomplete cortical maturation. This anatomo-pathological correlate may also impair previously acquired skills.

The neuropsychological examination represents a pivotal approach in the assessment of children with epilepsy, as it provides detailed information on the different developmental stages of specific cognitive domains.

Standardised tests assessing verbal memory, attention and frontal functions may thus be useful to detect and monitor cognitive impairments correlated with anatomical and electrophysiological data, within a more comprehensive assessment framework [53]. The strength of our study was to provide clinicians both with new diagnostic tools, as the short story parallel forms, and normative developmental data on tests known to tap specific higher cognitive functions in adults in a wide age range so far unavailable for the Italian population. The use of such tests will be critical for clinicians and researchers who need to monitor the effects of pharmacological and surgical treatments on young patients with epilepsy.

Sommario *In questo studio è stata standardizzata una batteria di test per la valutazione della memoria verbale a lungo termine (Breve Racconto), dell'attenzione (versione modificata delle Matrici Attenzionali e del Trail Making Test) e delle funzioni frontali (versione modificata della Frontal Assessment Battery) su una popolazione italiana di 283 soggetti in età evolutiva, di età compresa tra i 5 e i 14 anni. I punteggi grezzi di ogni test sono stati corretti per una serie di variabili (età dei soggetti, livello di scolarità dei genitori, dominanza manuale, sesso) e trasformati successivamente in punteggi equivalenti, che consentono un confronto diretto tra i punteggi ottenuti. Questo studio è stato promosso dalla LICE (Lega Italiana Contro l'Epilessia), al fine di ottenere la standardizzazione italiana su una popolazione in età evolutiva di una serie di test che valutano funzioni cognitive spesso deficitarie in pazienti affetti da epilessia.*

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Appendix

Short Story Test

Short Story Test 1

Anna/una bambina/di 8 anni/mentre tornava/da scuola/con il fratellino/vide/sul marciapiede/una scatola/tutta rossa./La aprì/ed ecco sbucare/il muso/di un gattino./ I due/bambini/corsero/a casa/contenti/e prepararono/una ciotola/con del latte/tiepido/e dei biscotti./Il gatto/Piero/mangiò/di gusto /e poi si addormentò/con la pancia /piena/e le zampe all'aria/sul tappeto/della nonna. /

Anna/a eight-year-old/girl/was coming back/from school/with her brother/when she saw/a red/box/on the pavement./She opened it/and a kitten/muzzle/appeared suddenly./The two/children/ran/home/happily/and prepared/a bowl/of warm/milk/and some biscuits./Piero/the cat /ate them/with gusto/and then fell asleep on his back /on grandmother's/carpet/with a full/belly/and his paws sticking up in the air /.

Short Story Test 2

Paolo/un ragazzino/di 10 anni/mentre andava/al parco/con un amico/vide/in piazza/un pagliaccio/tutto giallo./ Si fermò/e il clown/cominciò a tirare fuori/dal cappello/dei fiori/di carta./I due/bambini/attraversarono/la strada/incuriositi/e guardarono/ lo spettacolo/a bocca aperta./Alla fine/il pagliaccio/Alberto /si inchinò/con il cappello/in mano/ e poi lanciò/a tutti/una margherita/colorata. /

Paolo/a ten-year-old/boy/ was going/to the park /with a friend/when he saw/an all yellow/clown/ in the square./He stopped/and the clown/started taking/some paper/flowers/out of his hat./The two/curious/children/crossed /the street/and stared/open-mouthed/at the show./At the end/the clown/Alberto/bowed/with the hat/in his hand/and threw/a coloured/daisy/to everybody.

FAB: Frontal Assessment Battery [23]

1. "SERIE MOTORIE" (programmazione)
"Adesso facciamo un gioco insieme: guarda attentamente quello che faccio io". L'esaminatore, seduto davanti al bambino, esegue da solo per tre volte le serie di Luria "pugno – dorso – palmo". "Adesso, con la tua mano destra (se il bambino è mancino, con la mano sinistra), fai le stesse serie, prima insieme a me e poi da solo". L'esaminatore esegue le serie per tre volte con il bambino, poi gli dice: "Adesso continua da solo" e gli fa eseguire sei serie consecutive.

Il bambino esegue correttamente sei serie consecutive da solo:	3
Il bambino esegue correttamente almeno tre serie consecutive da solo:	2
Il bambino fallisce da solo, ma esegue correttamente le tre serie consecutive con l'esaminatore:	1
Il bambino non esegue correttamente le tre serie consecutive con l'esaminatore	0

1	2	3	4	5	6
si no	si no	si no	si no	si no	si no

2. "ISTRUZIONI CONFLITTUALI" (sensibilità all'interferenza)
"Adesso faremo un altro gioco. Quando io batto il pugno una volta, tu lo batti due volte". Per essere sicuri che il bambino abbia compreso il compito, si esegue una serie di tre prove: 1–1–1. "Adesso invece, quando io batto il pugno due volte, tu batti una volta". Anche in questo caso si esegue una serie di tre prove di verifica: 2-2-2. "Ora faremo insieme queste due cose, tu fai bene attenzione a quello che faccio io". L'esaminatore esegue la seguente serie: 1-1-2-1-2-2-2-1-1-2.

	1	*1*	*2*	*1*	*2*	*2*	*2*	*1*	*1*	*2*
R corr	*2*	*2*	*1*	*2*	*1*	*1*	*1*	*2*	*2*	*1*
R err	*1*	*1*	*2*	*1*	*2*	*2*	*2*	*1*	*1*	*2*
	non	*non*	*non*	*non*	*non*	*non*	*non*	*non*	*non*	*non*

Nessun errore:	3
Uno o due errori:	2
Più di due errori:	1
Il bambino batte come l'esaminatore almeno quattro volte consecutive:	0

3. INDICAZIONI "GO–NO GO" (controllo dell'inibizione)
"Questo è l'ultimo gioco. Adesso quando io batto il pugno una volta, anche tu lo batti una volta sola". Per essere sicuri che il bambino abbia compreso il compito, si esegue una serie di tre prove: 1-1-1.

"Quando io batto due volte invece, tu non devi battere". Si esegue nuovamente una serie di tre prove di verifica: 2-2-2. "Ora ne facciamo una serie insieme".

L'esaminatore esegue la seguente serie: 1-1-2-1-2-2-2-1-1-2.

	1	*1*	*2*	*1*	*2*	*2*	*2*	*1*	*1*	*2*
R corr	*1*	*1*	*non*	*1*	*non*	*non*	*non*	*1*	*1*	*non*

R err	*2 non*	*2 non*	*2 1*	*2 non*	*2 1*	*2 1*	*2 non*	*2 non*	*2 non*	*2 1*

Nessun errore: 3
Uno o due errori: 2
Più di due errori: 1
Il bambino batte come l'esaminatore almeno quattro volte consecutive: 0
Il bambino batte come l'esaminatore almeno quattro volte consecutive: 0

Soggetto: _____ Punteggio totale: _____

FAB: Frontal Assessment Battery [23]

1. MOTOR SERIES (programming)
"Let's play together: look carefully at what I'm doing". The examiner, seated in front of the patient, performs alone three times with his left hand the series of Luria "fist-edge-palm". "Now, with your right hand (the left hand if the patient is left-handed) do the same series, first with me, then alone." The examiner performs the series three times with the patient, then says to him/her: "Now, do it on your own".
Score:
Patient performs six correct consecutive series alone: 3

Patient performs at least three correct consecutive series alone: 2

Patient fails alone, but performs three correct consecutive series with the examiner 1

Patient cannot perform three correct consecutive series even with the examiner 0

1	2	3	4	5	6
si no	si no	si no	si no	si no	si no

2. CONFLICTING INSTRUCTIONS (sensitivity to interference)
"Now we'll do another game. Tap twice when I tap once" To be sure that the patient has understood the instruction, a series of three trials is run: 1-1-1. "Now, tap once when I tap twice". To be sure that the patient has understood the instruction, a series of three trials is run: 2-2-2. The examiner performs the following series: 1-1-2-1-2-2-2-1-1-2.

	1	*1*	*2*	*1*	*2*	*2*	*2*	*1*	*1*	*2*
Right answer	*2*	*2*	*1*	*2*	*1*	*1*	*1*	*2*	*2*	*1*
Wrong answer	*1* *no*	*1* *no*	*2* *no*	*1* *no*	*2* *no*	*2* *no*	*2* *no*	*1* *no*	*1* *no*	*2* *no*

No errors 3
One or two errors 2
More than two errors 1
Patient taps like the examiner at least four consecutive times 0

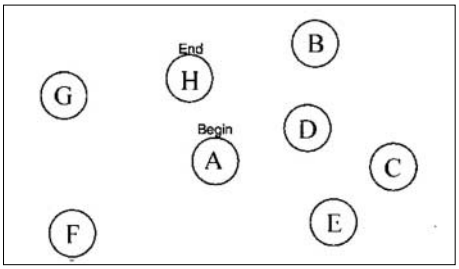
3. GO-NO-GO (inhibitory control)
"This is the last game. Tap once when I tap once" To be sure that the patient has understood the instruction, a series of three trials is run: 1-1-1. "Do not tap when I tap twice.". To be sure that the patient has understood the instruction, a series of three trials is run: 2-2-2. The examiner performs the following series: 1-1-2-1-2-2-2-1-1-2.

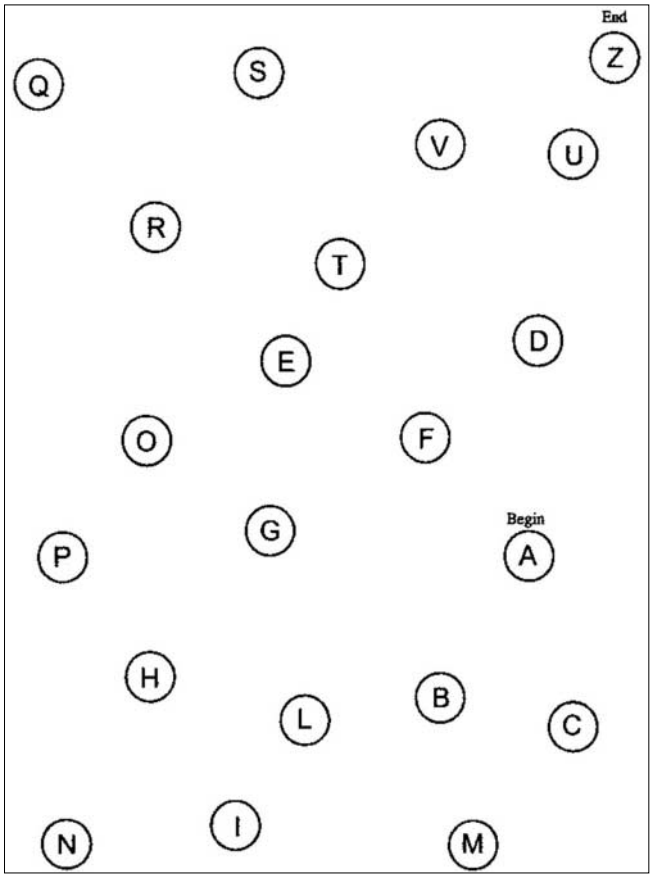
	1	*1*	*2*	*1*	*2*	*2*	*2*	*1*	*1*	*2*
Right answer	*2*	*2*	*1*	*2*	*1*	*1*	*1*	*2*	*2*	*1*
Wrong answer	*1* *no*	*1* *no*	*2* *no*	*1* *no*	*2* *no*	*2* *no*	*2* *no*	*1* *no*	*1* *no*	*2* *no*

No errors 3
One or two errors 2
More than two errors 1
Patient taps like the examiner at least four consecutive times 0

Subject: _____Total score: _____

Trail Making A/B





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