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Rhythm Reproduction in Kindergarten, Reading Performance at Second Grade, and Developmental Dyslexia Theories

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Abstract

Temporal processing deficit could be associated with a specific difficulty in learning to read. In 1951, Stambak provided preliminary evidence that children with dyslexia performed less well than good readers in reproduction of 21 rhythmic patterns. Stambak's task was administered to 1,028 French children aged 5–6 years. The score distribution (from 0 to 21) was quasi-normal, with some children failing completely and other performing perfectly. In second grade, reading was assessed in 695 of these children. Kindergarten variables explained 26% of the variance of the reading score at second grade. The Stambak score was strongly and linearly related to reading performance in second grade, after partialling out performance on other tasks (oral repetition, attention, and visuo-spatial tasks) and socio-cultural level. Findings are discussed in relation to perceptual, cerebellar, intermodal, and attention-related theories of developmental dyslexia. It is concluded that simple rhythm reproduction tasks in kindergarten are predictive of later reading performance.

Keywords: Rhythm reproduction; Reading acquisition; Dyslexia

Introduction

The temporal processing deficit hypothesis is one possible explanation of developmental dyslexia (i.e., specific impairment in learning to read in schoolchildren of normal intelligence, without neurological or sensory impairment). Dyslexia has been attributed to a difficulty in establishing links between graphemes and phonemes, due to confusion between phonemes (e.g., ba–da) related to a deficit in processing sequences of brief auditory stimuli (Tallal, 2004; Tallal & Piercy, 1974). Although this specific statement has been criticized (Habib, 2000), there is strong empirical evidence that most children with difficulty in learning to read have also difficulties processing temporal sequential information. For example, children with dyslexia showed difficulties in detecting a gap during auditory stimulation (Hautus, Setchell, Waldie, & Kirk, 2003; Llinas, Ribary, & Tallal, 1998); temporal-order judgment in kindergarten was associated with reading level in first grade (Hood & Conlon, 2004); temporal duration judgment correlated with reading performance in college students (Walker, Shinn, Cranford, Givens, & Holbert, 2002); difficulties with sequences and temporal perception in dyslexics were reported not only with auditory stimuli but also with visual, tactile, and cross-modal stimuli (Laasonen, Service, & Virsu, 2002).

The idea that specific impairment in learning to read is associated with difficulties in perception and treatment of temporal information is an old one. In 1951, Stambak asked 230 normal children aged from 6 to 12 years to reproduce 21 rhythmic patterns of increasing complexity (Fig. 1), and observed: (a) a strong variability in performance at age 6 (median = 9

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Training-: (a) ** (b) * *

Items	Items	Items
1) ***	8) ** ** **	15) * * * **
2) ** **	9) ** ***	16) ** *** *
3) * **	10) * * * *	17) * **** **
4) * * *	11) * ****	18) ** * * **
5) ****	12) *****	19) *** * ** *
6) * ***	13) ** * **	20) * ** *** **
7) ** * *	14) **** **	21) * ** ** * **

** : about 250 ms ; * * : about 1 sec

Fig. 1. Stambak task: reproduction of 21 rhythmic patterns.

errors, inter-quartile interval = 7); (b) a strong developmental effect (at age 9: median = 3 errors); (c) low performance in this task for children with dyslexia (Stambak, 1951, 1992).

Recent studies confirmed the association of rhythm with language development and learning to read (Wolff, 2002). Members of a family with hereditary speech and language disorder showed deficient rhythm perception and reproduction in both vocal and manual modalities, without difficulties in pitch perception (Alcock, Passingham, Watkins, & Vargha-Khadem, 2000). Adults with a history of specific language impairment in childhood presented lower rhythmic skills than controls (Kenney, Barac-Cikoja, Finnegan, Jeffries, & Ludlow, 2006). Children with dyslexia (aged 7–11 years) performed worse than controls in musical tasks involving rhythm and time (e.g., count the number of taps) but better than controls in pitch tasks (Overy, Nicolson, Fawcett, & Clarke, 2003). Rhythm pattern detection was found to be deficient in adult dyslexics, both with verbal (syllables) and non-verbal visual, auditory, or cross-modal stimuli (Meyler & Breznitz, 2005). Children with difficulties in learning to read in first and second grade showed lower performance on the Seashore rhythm test (McGivern, Berka, Languis, & Chapman, 1991). Also, children with attention deficit hyperactivity disorder (ADHD) and dyslexia had more difficulties with the reproduction of complex rhythm patterns than children with ADHD without dyslexia (Tiffin-Richards, Hasselhorn, Richards, Banaschewski, & Rothenberger, 2004).

It was suggested that segmentation of speech and syllable detection depends on rhythm perception (Hannon & Johnson, 2005; Morgan & Saffran, 1995). According to a recent hypothesis, sensitivity to the shape of amplitude modulation could explain the link between rhythm and syllable detection (Goswami et al., 2002; Muneaux, Ziegler, Truc, Thomson, & Goswami, 2004).

The main goal of the present longitudinal study was to examine the relation between rhythm reproduction in kindergarten and reading performance in second grade in a very large sample of unselected normally developing children. More specific questions were: (a) is there a significant association between rhythm reproduction in kindergarten and learning to read in second grade? (b) Is this association specific to children who have difficulties learning to read, or on the contrary is there a linear trend between rhythm and reading? (c) Can this association be completely explained by factors known to be related to learning to read, such as socio-economic status (SESs), phonological, memory, or attention skills?

Materials and Methods

Participants

This research is based on data from a longitudinal study conducted in France in kindergarten and elementary schools (Chevrie-Muller, Watier, Arabia, & Dellatolas 2005; Watier, Dellatolas, & Chevrie-Muller, 2006; Dellatolas, Watier, Giannopulu, & Chevrie-Muller, 2007). The kindergarten sample included 1,028 children, and 695 of them were followed through second grade. The study took place in Paris and its suburbs. All SESs were represented. For each child: (i) SESs of the family were classified as either (a) low, (b) median, or high; with low SES corresponding to working classes with parents' educational levels not higher than the end of elementary schooling; (ii) bilingualism was considered present when a language other than French was primary for at least one of the parents; (iii) the geographic area of the school was scored as "difficult" or "not difficult", according to the French National Institut of Demographic studies (INED); "difficult" areas, also labeled "educational priority areas," are those with socio-economic difficulties and schools in these areas receive additional public funding. Table 1 describes the kindergarten and second grade samples. No significant difference was

Table 1. Description of the kindergarten and second-grade samples

	Kindergarten	Grade 2
N	1,028	695
Age (months): m (*SD*)	67.2 (2.6)	89.3 (3.2)
Sex (% boys)	49.9	48
SES (% low)	35.4	35.3
Bilingualism (%)	21.3	21.0
% Disadvantaged School Area	24.6	24.4

Note: SES = socio-economic status.

observed between kindergarten children who were followed until second grade ($n = 695$) and those who were not ($n = 333$) for the variables presented in Table 1 or for performance on the following eight kindergarten tasks.

Tasks in Kindergarten

(1) *Oral repetition of difficult words* (ORW). This task included six multisyllabic and rare words. Each word was pronounced by the examiner and the oral repetition by the child was scored from 0 = absence or unrecognizable to 3 = correct (max = 18) (Chevrie-Muller, Simon, & Decante, 1981)
(2) *Oral repetition of digits* (ORD). This six-item task included three series of 3 digits and three series of 4 digits. The child was asked to repeat each item respecting the order and his/her performance was scored as 1 = correct or 0 = incorrect (max = 6) (Chevrie-Muller et al., 1981)
(3) *Oral repetition of sentences* (ORS). The child was asked to repeat three sentences. The maximum score was seven points for the first, six points for the second, and seven points for the third (max = 20) (Chevrie-Muller et al., 1981)
(4) *Story recall* (SR). The examiner reads a story and then asks the child to repeat it. The story is divided into 11 parts to facilitate scoring (max = 11) (McCarthy, 1976).
(5) *Thurstone's cancellation task* (THU). This 60-item task involves visual attention and processing speed. Each item is composed of three drawings of schematic faces, two identical and one different. The child is asked to cancel the "different" one. The score is the number of faces correctly cancelled in 6 min (max = 60) (Thurstone & Yela, 1985).
(6) *Drawing a man task* (DM). The child is asked to draw a man and performance is scored based on Goodenough (1973) (max = 51).
(7) *Copy of figures* (CF). The child is asked to copy a cross (1 point), a circle (1 point), a square (2 points), a triangle (2 points), and a diamond (4 points) (max = 10) (Chevrie-Muller, Simon, Le Normand, & Fournier, 1988).
(8) *The rhythm reproduction (RR) task*. The examiner produces each of 21 rhythms (Fig. 1) out of the view of the child (under the table or behind a screen). After each item, the child is asked to produce exactly the same thing tapping with a pencil on the table. An item is scored 0 if the child fails to reproduce the rhythm after two successive presentations of the same structure, and 1 otherwise (success after the first or the second presentation). The 12 first items are systematically presented; after the 12th item, the task is stopped after three successive failures. The examiner was trained to produce approximately 250 ms and 1 s intervals (Stambak, 1951).

Tasks in Second Grade

Children were asked to perform five tasks assessing reading and phoneme–grapheme transcription:

(1) *Dictation of phonemes, syllables, sentences, and text*. This task included (a) dictation of a list of 10 phonemes and syllables; (b) dictation of two sentences; (c) dictation of a text. For parts (b) and (c), cotation was based on correctly transcribing predefined items, syllables, or words (Savigny, 1974).
(2) *Reading of letters and syllables*. This task included 20 items, letters or syllables, to measure whether the child is able to correctly apply the decoding rules of written French (Savigny, 1974).
(3) *Reading of 10 regular words* (Sprenger-Charolles, Siegel, Bechennec, & Serniclaes, 2003).
(4) *Reading of 10 non-words* (Sprenger-Charolles et al., 2003).
(5) *Reading comprehension of simple sentences*. The child had to complete 19 drawings according to a written instruction, for example, "put a hat on the boy's head" (Inizan, 1988).

Statistical Analysis

Statistical analysis was performed with SAS software (SAS Institute Inc., Cary, NC, USA), and focused on the relation between kindergarten rhythm reproduction (RR) performance and reading score in second grade.

The five reading tasks in second grade were strongly intercorrelated, with a principal component analysis showing only one factor accounting for 74% of the variance. This justifies the calculation of a total score in second grade, summing up the scores of the five tasks. To give the same weight to each task, *z*-scores were used to create the total score. Contrary to the quasi-normal distribution of kindergarten RR (Fig. 2), the total second grade reading score (which is a sum of five *z*-scores) had an asymmetrical distribution, indicating that many children succeeded nearly perfectly the reading tasks and, in contrast, in children with reading delay, the degree of this delay was very variable. A small number of children obtained strongly negative scores, which means that these children failed at almost all reading tasks (Fig. 3).

A regression analysis was conducted, first, with reading score at second grade as the dependent variable and 12 covariates: sex, SESs, school area, bilingualism, and all eight scores on the kindergarten tasks.

A logistic regression was performed, second, where children with a total reading score lower than −5 (8% of all children) were considered as having possible dyslexia. This cut-off can be justified by reported prevalences of dyslexia in the general population (e.g., between 5.3% and 11.8% depending on the criteria used, according to Katusic, Colligan, Barbaresi, Schaid, & Jacobsen, 2001; 7.5% according to Shaywitz, Shaywitz, Fletcher, & Escobar, 1990). We used the term reading delay for these children because there were only in second grade. The term delay does not imply that these children will catch-up at some point.

To examine further whether the RR-reading relation was mainly due to children with reading delay or on the contrary linear (i.e., is RR different in children with high reading performance compared with those with median reading performance?), five equal groups of children were defined according to their total reading score at second grade: Group 0 includes the 20% of children with the lowest scores, Group 4, the 20% with the highest scores, Groups 1, 2, and 3 were intermediate. To examine the association of RR with the five reading groups defined above, the proportional odds ratio (OR) model described by McCullagh (1980) was used. This model postulates that the OR is the same for all binary variables (from 1 vs. 2, 3, 4, 5 to 1, 2, 3, 4 vs. 5, in the case of five groups). This assumption can be tested.

In addition, Pearson and Spearman correlations, chi-square, and factor analysis were used.

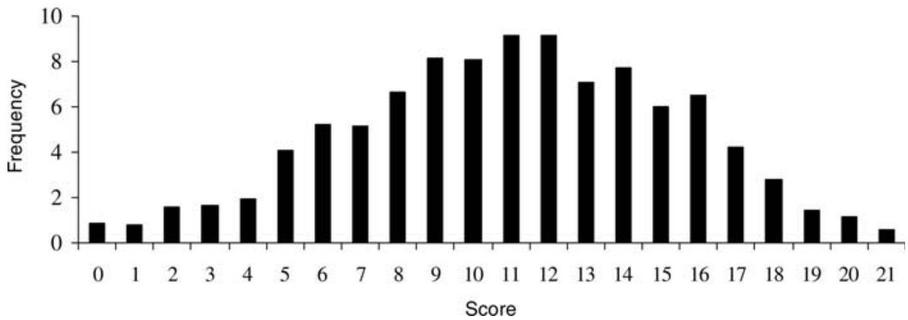

Fig. 2. Histogram of rhythm reproduction scores for 1,028 children in kindergarten.

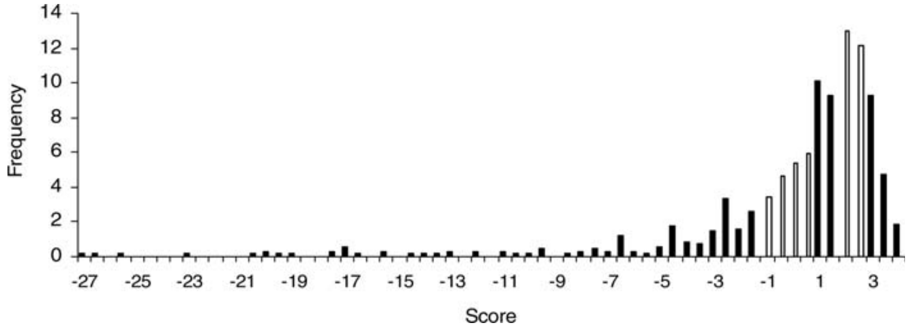

Fig. 3. Histogram of reading scores for 695 second-grade children. Black and white bars indicate the five reading groups.

Results

Kindergarten Tasks

Rhythm reproduction performance showed a quasi-normal distribution, with mean and median values equal at 11, $SD = 4.3$ and range 0–21 (Fig. 2). All kindergarten tasks were significantly correlated with RR in this very large sample, with Spearman's $\rho > .25$ for oral repetition tasks only (Table 2). Correlations between recall of a story and repetition of sentences, as well as between the three oral repetition tasks were high ($\rho > .40$) (Table 3).

Reading in Second Grade and Kindergarten Tasks

Correlations

All kindergarten tasks were significantly related to the reading score; however, correlations were low with "drawing a man", story recall, and copy of figures (Table 2).

Regression Analysis: Reading Score in Second Grade as a Dependent Variable

When all 12 covariates (sex, SESs, school area, bilingualism, and all eight scores at kindergarten tasks) were included in the model, coefficients of four covariates only ("drawing a man", story recall, copy of figures, and bilingualism) did not reach significance. After exclusion of these four covariates, the model obtained is shown in Table 4, with all covariates significant. No collinearity was observed. The model explained 26% of the variance of the reading score ($R^2 = 0.262$). SESs had the strongest effect, reading was better when the geographic area of the school was favorable, and slightly better in girls than boys. Among the five kindergarten scores, RR had the strongest effect, followed by ORW.

The correlation of RR with reading score was significantly higher in children from low SESs ($r = 0.38$, $\rho = 0.47$, $N = 219$, $p < 0.0001$) than in those from median to high SESs ($r = 0.26$, $\rho = 0.33$, $N = 401$, $p < 0.0001$) (test for interaction: RR: $F(1,616)=84.0$, $p < 0.001$; SES: $F(1,616)=51.0$, $p < 0.001$; RRxSES: $F(1,616)=23.1$, $p < 0.0001$).

Two Reading Groups: Children with Reading Delay (8%) versus Other Children (92%)

A logistic regression with the same eight covariates as above, retained the model shown in Table 4. School area and SESs had strong effects, and RR was the only kindergarten task with a significant effect. A backward selection retained the above three covariates and in addition ORW. The RR × SES interaction did not reach significance in this model ($p = 0.18$) despite the tendency of better prediction of reading delay in children with low SES than in children with median–high SESs (Fig. 4).

Table 2. Mean (*SD*) of kindergarten tasks and their correlation (Spearman rho) with Rhythm Reproduction (RR) Performance ($N = 1028$), and reading at Grade 2 ($N = 695$). (The kindergarten tasks were not given at second grade)

	m (*SD*)	Rho with RR ($N = 1{,}028$)	Rho with Grade 2 reading ($N = 695$)
Rhythm Reproduction (RR)	11.0 (4.3)		0.32
Draw a Man (DM)	12.2 (3.7)	0.14	0.16
Copy of Geometric Figures (CF)	6.9 (2.2)	0.14	0.26
Story Recall (SR)	5.2 (2.8)	0.10	0.17
Oral Repetition of Difficult Words (ORW)	14.3 (3.5)	0.30	0.36
Oral Repetition of Sentences (ORS)	14.4 (4.4)	0.29	0.35
Oral Repetition of Digits (ORD)	4.8 (1.4)	0.35	0.37
Thurstone (THU)	17.9 (8.3)	0.25	0.33

Table 3. Spearman correlations (ρ) between kindergarten tasks ($N = 1{,}028$)

	DM	CF	SR	ORW	ORS	ORD	THU
DM		0.30	0.10	0.09	0.11	0.15	0.14
CF			0.08	0.17	0.12	0.17	0.26
SR				0.27	0.43	0.21	0.21
ORW					0.49	0.43	0.21
ORS						0.49	0.25
ORD							0.20

Notes: All correlations are significant (e.g., $p < 0.01$ for $\rho = 0.08$ and $N = 1028$). DM = draw a man; CF = copy geometric figures; SR = story recall; ORW = oral repetition of difficult words; ORS = oral repetition of sentences; ORD = oral repetition of digits; THU = Thurstone's cancellation task.

Table 4. Multivariate analysis

Variables	Linear Regression[a]			Logistic Regression[b]		
	$\hat{\beta}$	$\hat{\alpha}$	p	$\hat{\beta}$	$\hat{\alpha}$	p
RR	0.14	0.04	0.0002	0.10	0.05	0.03[c]
ORW	0.16	0.05	0.002	0.07	0.05	0.17[c]
ORS	0.10	0.04	0.02	0.06	0.05	0.18
ORD	0.37	0.13	0.005	0.17	0.12	0.15
THU	0.05	0.02	0.01	0.04	0.03	0.12
SES	−1.42	0.33	<0.0001	−0.99	0.37	0.008[c]
Sex	−0.61	0.30	0.04	−0.08	0.34	0.81
SchA	−1.07	0.36	0.003	−1.21	0.35	0.0005[c]

Notes: RR = rhythm reproduction; ORW = oral repetition of difficult words; ORS = oral repetition of sentences; ORD = oral repetition of digits; THU = Thurstone's cancellation task; SES = socio-economic status; SchA = school area.

[a]Dependent variable, the reading score at second grade; simultaneous regression.

[b]Dependent variable, presence/absence of reading delay at second grade; children with delay were those with the lower 8% of reading scores; simultaneous regression.

[c]RR, ORW, SES, and SchA are the only variables retained by a backward selection, with $p = 0.003$, 0.002, 0.0009, and 0.0002, respectively.

To illustrate the association of RR with reading delay, different cut-offs may be chosen on the RR score to examine the proportion of children with delay having low RR (sensitivity) and that of children without reading delay having higher RR (specificity). For RR < 7 (15% of the children), sensitivity is 0.40 (e.g., 40% of the children with reading delay at second grade had RR < 7 at Kindergarten), and specificity 0.87 (e.g., 87% of the children without reading delay at second grade had RR ≥ 7 at Kindergarten) ($\chi^2 = 26.6$, $df = 1$, $p < 0.0001$). For RR < 10 (35% of the children), sensitivity is 0.66, and specificity 0.68 ($\chi^2 = 24.6$, $df = 1$, $p < 0.0001$).

Five Reading Groups and RR Performance: Univariate analysis

Mean RR performance differed significantly ($p < .0001$) according to the reading group: Group 0, 8.49, IC95% [7.86–9.10]; Group 1, 10.47 [9.74–11.20]; Group 2, 11.18 [10.57–11.79]; Group 3, 12.13 [11.44–12.82]; Group 4, 13.63 [12.96–14.30] (Fig. 5). The proportional OR hypothesis was not rejected ($\chi^2 = 2.01$, df = 3; $p = 0.57$).

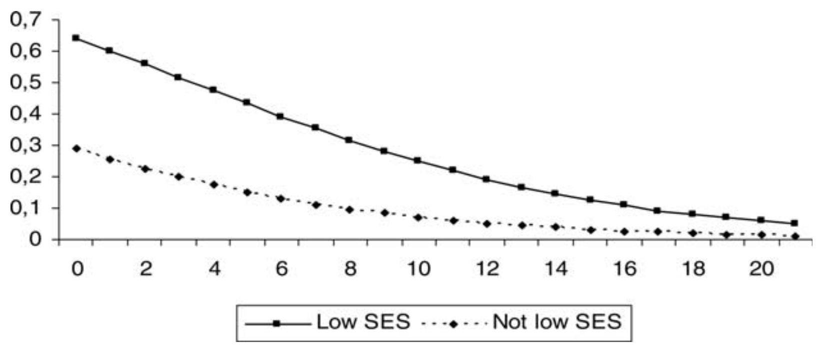

Fig. 4. Probability estimations to have a reading delay as a function of RR performance and SESs.

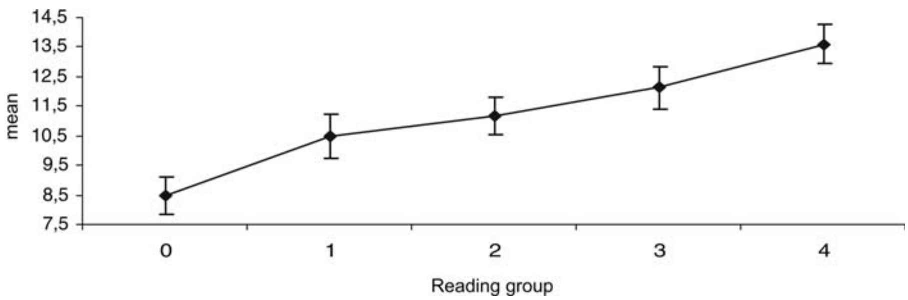

Fig. 5. Mean (CI95) of RR performance as a function of reading group.

Discussion

The present study shows that (a) there is a significant association between rhythm reproduction and learning to read; (b) this association is not specific to children with learning to read difficulties, but on the contrary there is a linear trend between rhythm and reading: the better the performance on rhythm reproduction in kindergarten, the better the reading performance in second grade; (c) this association cannot be completely explained by factors known to be related to learning to read, such as SESs, or other cognitive skills assessed by other kindergarten tasks, involving phonological, working, or verbal semantic memory, visual attention and processing speed, or visuo-spatial skills.

Kindergarten tasks, SESs, and school area explained only 26% of the variance of the reading score. This suggests that additional factors, not examined in the present study, have an important impact on reading performance at second grade. Such factors may be related to phonological, attentional, and visual skills or to IQ, and some of them may act after the kindergarten period.

The linear trend between RR and reading is in accordance with a few previous studies reporting a link between temporal processing and reading even in participants without dyslexia. Meyler and Breznitz (2005) found an association of processing of temporal structures with reading in adults without dyslexia. Walker and colleagues (2002) reported that discrimination of duration was associated with reading performance both in participants with dyslexia and in controls.

Among the eight kindergarten tasks, only two remained related to very low reading performance in second grade (RR and ORW); in contrast, five kindergarten tasks remained significant when reading was considered a continuous variable. The additional three tasks contributed to the prediction of average versus good later reading, but not to the prediction of reading delay. Also, although SESs and school area had an effect both for reading delay (two reading groups) and for overall reading performance, gender had a small effect only on the latter. This suggests that girls are more often good readers in second grade than boys, but present reading delays as often as boys.

The quasi-normal distribution of RR performance in kindergarten children aged 5–6 years is consistent with early observations of Stambak (1951) in a small sample. In 48 children aged 6 years, she observed a mean of nine errors and a symmetrical distribution with strongly variable performance. Stambak's data also show a strong developmental effect, RR performance increasing dramatically from age 6 to age 12 years.

As expected, RR performance was correlated mainly with oral repetition tasks, which involve auditory tracking, and less with tasks assessing visuo-spatial skills or semantic memory. The same oral repetition tasks were also those preferentially correlated to later reading; however the RR relation to reading remained significant after partialling out oral repetition effects. A limit of the present study is that some reported early predictors of later reading, especially phonological awareness and rapid naming (Snowling, Goulandris, Bowlby, & Howell, 1986; Wolf, Bowers, & Biddle, 2000), were not assessed in Kindergarten. It remains to be seen if the RR performance–reading association remains significant when such additional factors are taken into account.

Low SESs and "difficult" school context had a strong negative effect on overall reading performance in second grade, and also increased the probability for the child to have a reading delay (i.e., being in the group with the lower 8% reading scores). Kindergarten RR performance remained significant when these environmental factors were taken into account, but for overall reading performance its effect was stronger in the case of low SES. Such strong environmental effects question the qualification of all children with low reading scores as "with dyslexia".

The above observations are not compatible with a specific temporal processing deficit that would be present exclusively in some children with difficulties learning to read. The fact that a quasi-normal distribution was observed in kindergarten suggests that many factors determine RR performance in children aged 5–6 years. These factors could be:

- (i) perceptual ability (bottom-up), such as differential skill in perception of duration (Walker et al., 2002) or beat detection (Goswami et al., 2002);
- (ii) motor ability, for example, variable ability to execute rapidly successive identical movements, possibly related to differential maturation of corresponding brain structures such as the cerebellum (Nicolson, Fawcett, & Dean, 2001). It is known that cerebellar lesions may compromise execution of rapidly successive movements (adiadochocinesia), and this structure has been involved in timing (Ivry, 1997) and automaticity (Doyon et al., 1998). However, further studies are needed to examine whether children with cerebellar pathologies present with specific reading difficulties, perceptual impairment in rhythm detection (and not only in rhythm reproduction), or automaticity-related reading difficulties. In addition, motor programs could be involved in oral and written language perception: it has been suggested that there is activation of articulatory programs that allow a rapid analysis and comprehension of language input (Liberman, Cooper, Shankweiler, & Studer-Kennedy, 1967; Ingvar, 1998);

(iii) intermodal processing ability: in RR performance, the child has to transform an acoustic signal to motor execution, and a relation between intermodal tasks and reading performance has been repeatedly reported elsewhere (Denckla & Rudel, 1974; Plaza & Cohen, 2005);

(iv) attentional or working memory abilities (top-down): the critical factor in RR could be the more or less active participation of the child while hearing the rhythms, which could involve some form of subvocal rehearsal (Baddeley, 1992). A strong developmental trend in RR performance could argue in favor of this hypothesis, as the capacity to maintain focalized attention increases with age (Cowan, 1997). Also, subvocal rehearsal is not used spontaneously by young children, who nevertheless could be able to use it after explicit instructions (Bjorklund & Douglas, 1997).

All the above factors have been proposed in developmental dyslexia. The present study suggests that some of them are not specific to children with significant reading difficulties, but could also explain variable reading performance in the general population. In practice, RR performance at kindergarten age seems to be an interesting task for early detection of children at risk for reading delay.

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Conflict of Interest

None declared.

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