Design of the rhythmic tasks of a computer-assisted phonological training to improve reading abilities in first-graders

Andrea Prato
INRiM (National Institute of Metrological Research), Italy.

Giuseppina Emma Puglisi
Department of Energy, Politecnico di Torino, Italy.

Arianna Astolfi
Department of Energy, Politecnico di Torino, Italy.

Tiziana Sacco
Department of Neuroscience, Università degli Studi di Torino, Italy.

Summary

There is growing evidence that reading disorders (e.g. dyslexia) are likely to be due to impairments in the phonological processing. Possible causes are associated with a complex interaction of genetic factors (50-80%) and environmental risk factors (20-50%). According to the "rise-time theory", impairments in phonological processes across languages are due to difficulties in processing the speech sound structure, specifically its amplitude modulation. This is related to a deficit in discriminating the speech amplitude envelope rise-time (i.e. the time required to reach a speech peak), which affects the detection of speech rhythm and prosody. In this context, it is argued that rhythmic interventions may improve rhythmic entrainment and consequently improve reading and phonological skills, as found in literature on primary and high-school poor readers. In particular, since the neuroplasticity of the auditory cortex is still high before 7 years, trainings administered in the early childhood can produce more positive effects. In this work, the design of the rhythmic tasks, which are part of a more extended computer-assisted phonological training, is shown. The section designated to enhance the rhythmic abilities resulted in a 5-hours rhythmic training overall. 97 first-graders from six classes of three different primary schools located in Torino (Italy) were involved in the trial. The rhythmic tasks, based on recent scientific outcomes, were individually and simultaneously administered to all children in their classrooms via tablet and headphones in 15 weekly sessions of 20-min. Improvements after the intervention period were compared with those of a matched control group of 82 first-graders from other three primary schools. Preliminary results indicate that the administration of the phonological training enhanced with the rhythmic tasks had a positive effect on the rhythmic perception and discrimination.

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1. Introduction

Learning to read is a linguistic process, where speech and auditory processing skills play a crucial role [1]. The speech signal carries information at different phonological levels (i.e. intonational phrase, stressed syllable, syllable and phoneme) at multiple temporal scales, and the brain processes both slow and fast energy modulations simultaneously. According to the Temporal Sampling theory [2], an oscillatory hierarchy in brain at rates of 1 Hz, 2 Hz, 5 Hz and 35 Hz, which correspond to phrase, stressed syllable, syllable and phoneme, respectively, underpins the neural encoding of speech, a process called phase alignment (neuronal entrainment) [1,3]. Dyslexia is neurological in origin and its cause is associated with a complex interaction of genes factors (50-80%) and environmental risk factors (20-50%) [4,5]. According to the recent Rise Time theory, children with developmental dyslexia show impairments in processing this speech sound structure [6], particularly its amplitude modulation. This is likely to be due to a deficit in discriminating the speech amplitude envelope rise-time (i.e. the time required to reach a speech peak), which affects the detection of speech rhythm and prosody [1,7]. Slow energy fluctuations, related to speech prosody and rhythm (Figure 1) and to difficulties in recovering prosodic and rhythmic structure from the speech signal, underpin the phonological deficit that causes reading impairment [8]. All languages vary syllable stress and prosodic phrasing; therefore, a low-frequency envelope encoding impairment is expected to affect reading development in all languages, even in those that do not use an alphabetic orthography (i.e. phoneme-based) [10]. Based on this evidence, a computer-assisted phonological training program designed to enhance the perception of rhythm in language (using beats, clapping and drumming), which is shown to improve the reading abilities in children [11-17], was designed and developed for first graders, i.e. to children between 6 and 7 years, when the neuroplasticity of the auditory cortex is still high [18].

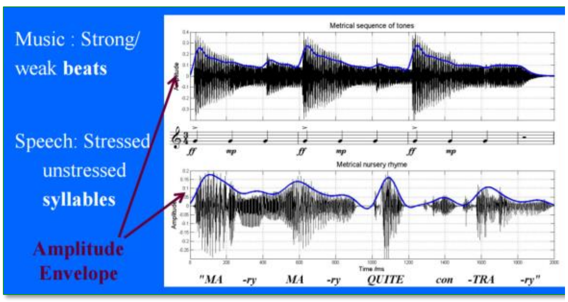

Figure 1. Prosodic and rhythmic structure of speech. Image taken from the presentation of U. Goswami, keynote speaker at EDA 2016 [9].

2. Participants

179 first grade children aged between 6 and 7 years voluntarily participated in the study, after their parents signed an informed consent. The training was administered to 97 children (TG=training group), whereas the remaining 82 acted as control group (CG). Children were recruited from 6 schools (11 second-grade classes in total: 3 classes from school A, 2 from school B, 2 from school C, 2 from school D, 1 from school E, 1 from school F) located in Torino, Italy. Subdivision of TG and CG is reported in Table I.

Table I. Distribution of schools, classes and children.

School	*Class*	*Number of children*	*Group (T=training, C=control)*
A	1	14	T
A	2	15	T
A	3	18	T
B	4	16	T
B	5	18	T
C	6	16	T
C	7	18	C
D	8	18	C
D	9	17	C
E	10	21	C
F	11	8	C

The schools had differences in urban location in order to take into account possible environmental differences. Subdivision of TG and CG within classes was performed in order to have two homogeneous groups. The training was administered to all children in their classrooms within the school-hours between February and June 2017.

3. Rhythmic tasks of the computer-assisted phonological training

The computer-assisted training was designed to improve the children’s phonological and rhythmic skills. It was based on different rhythm exercises, delivered via tablet and headphones to every child of each class simultaneously. It was presented in form of a PowerPoint® presentation, with successive exercises that did not allow for answers or response times collection, but allowed for the appearance of positive or negative feedbacks in form of emoticons. The training was administered once a week along 15 sessions of 1 hour, in order to cover a total of 15 hours. Rhythmic tasks represented one third of the total training, i.e. 5 hours out of 15 (20 minutes per session). Different rhythmic tasks were designed based on literature review [11-17] and are described in the following Subsections. All stimuli were programmed using Audacity® and Ableton Live® software. Answers and response times were not acquired during the training. The effectiveness of the training was evaluated through pre- and post-tests that were aimed at testing the ability of children in discriminating sounds and rhythms, as described in Section 4.

3.1. Clapping along a metronome or beat

The children heard click tracks or simple beat tracks (kick and snare sounds) at different tempos between 60 and 140 bpm. The stimuli were delivered simultaneously through loudspeakers to all children in their class. Children were instructed to clap at the same time as the stimulus. Each tempo was played for 36 beats, therefore faster tempos had shorter durations. Six randomized different tempos were administered once a session for a total of 15 times.

3.2. Discrimination between two tempos

The children heard two click or beat tracks and they had to determine the fastest one. Children had the possibility to click on the first and second track separately and for several times. Tempos of stimuli ranged between 60 and 140 bpm and each beat lasted 4 beats. As the intervention progressed, the difference between the tempos decreased, making each trial more difficult than the previous one. If the child responded incorrectly, a negative feedback (sad emoticon) appeared on the screen encouraging the child to respond correctly. In case of correct answers, a positive feedback appeared and the sequence was reproduced again. The task was administered 4 times in total, and, each time, around 10 random exercises were presented.

3.3. Discrimination between two rhythmic sequences

The children heard two rhythmic sequences of 8 beats and separated by 4 beats of silence, with tempos between 60 bpm and 140 bpm. Rhythmic sequences based on beats were composed of 500 Hz tone bursts of 200 ms of duration. Children had to determine whether the two rhythmic sequences were the same or different. The rhythmic sequences became more complex as the intervention progressed. Correct and incorrect answers were followed by positive or negative feedback, as in the previously described task. This task was administered 8 times throughout the intervention. For each session, around 10 random exercises were presented.

3.4. Amplitude rise-time discrimination task

Children listened to two stationary tones at 500 Hz, but with different rise times (onset or attack time). They had to decide which of the two sounds had a longer rise time, i.e. which sound began more softly. Tones had the same time duration of 800 ms. A total of 35 stimuli were created. Rise-times ranged between 0 ms to 2000 ms with with steps of 15 ms from 0 to 300 ms, of 50 ms from 300 ms to 750 ms, and of 250 ms from 750 ms to 2000 ms. The task became more complex as the intervention progressed. Correct and incorrect answers were followed by a positive or negative feedback, as in the previous tasks. This task was administered 8 times throughout the intervention with around 10 random exercises per session.

3.5. Singing a rhythmic sequence

The children heard a metronome or a rhythmic sequence of 36 beats, similar to those used in Subsection 3.3. Participants were encouraged to simultaneously mimic aloud the rhythm using different syllable, e.g. ‘‘la-la’’, “mi-mi”, “bi-bi”. The rhythmic sequences were designed to become more complex as the intervention progressed, for example changing the syllables every 4 beats in order to form a full sense phrase of 9 syllables (e.g. “La mam-ma cu-ci-na in ca-sa” which is the Italian translation of “Mum is cooking at home”). This task was administered at each training session, i.e. 15 times, and for each session 3 exercises were presented.

4. Preliminary results

The effectiveness of the rhythmic training was evaluated based on the rhythmic perception and discrimination tests that were administrated to each child before and after the intervention, to both trained and control groups. Tests were administrated to children in one-to-one sessions by a trained experimenter. The rhythmic test consisted in 7 questions on the discrimination between two rhythmic sequences and was measured in terms of number of correct answers, thus rhythmic test scores ranged between 0 and 7. Each experimenter was trained to report the same information about the test, so it has been possible to reduce the inter-experimenter variability making it negligible for the subsequent analyses. Rhythmic score distributions of TG and CG in pre- and post-tests are shown in Figure 2. The normality test of Shapiro-Wilk revealed that all distributions were not normal (p-value<0.05), thus nonparametric tests were subsequently used. Firstly, the Mann-Whitney U test was performed between rhythmic scores distributions of TG and CG of pre-test. No significant differences (p-value=0.723) were found, therefore the two groups can be considered

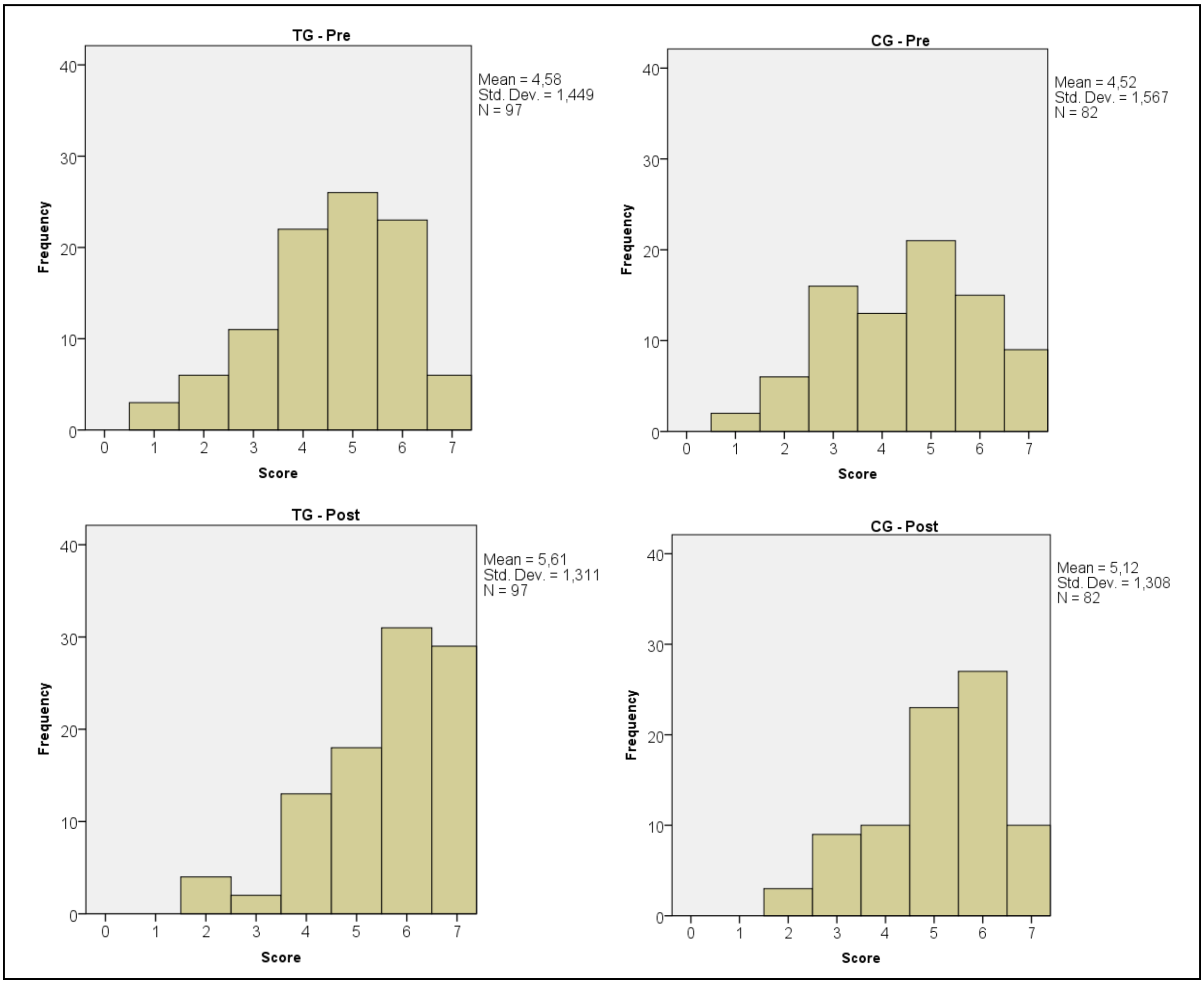

Figure 2. Rhythmic score distributions of pre- (top) and post- (down) tests of TG (left) and CG (right).

homogeneous, that is, among all the data acquired, it cannot be stated that the starting abilities of children in TG and in CG were different. Subsequently, rhythmic scores distributions of TG in pre- and post-tests were analyzed through the Mann-Whitney U test and a significant difference between the two conditions (p-value=$4\cdot10^{-7}$) was found. The same test was applied to the scores distributions of CG in the two periods. Also in this case a significant difference (p-value=0.012) was found. This means that children from both groups significantly improved their rhythmic skills. Nevertheless, since the p-value of TG is 5 orders of magnitude smaller than the CG's one, it is possible to assume that trained children enhanced their rhythmic skills more than children of the control group, whose improvements are only due to the natural development of rhythmic skills over time. Another comparison was performed through Δ score values, which are the child-by-child differences between pre- and post- test scores. Δ scores distributions of TG and CG are shown in Figure 3. Mean value of the TG is higher than mean value of the CG. Mann-Whitney U test performed between these two distributions showed a p-value of 0.079, thus the difference between TG and CG is significant at a level of 0.10 but not at the standard significance level of 0.05. This result shows the positive effect of the training to improve rhythmic skills of children. Nevertheless, a stronger significance is needed to confirm the effectiveness of the intervention.

5. Conclusions

Children affected by dyslexia show impairments in processing this speech sound structure, specifically its amplitude modulation that affects the detection of speech rhythm and prosody. For this reason, since the neuroplasticity of the auditory cortex is still high before 7 years, a computer-assisted phonological training was designed for first-graders in order to improve rhythmic entrainment and consequently to improve their reading and

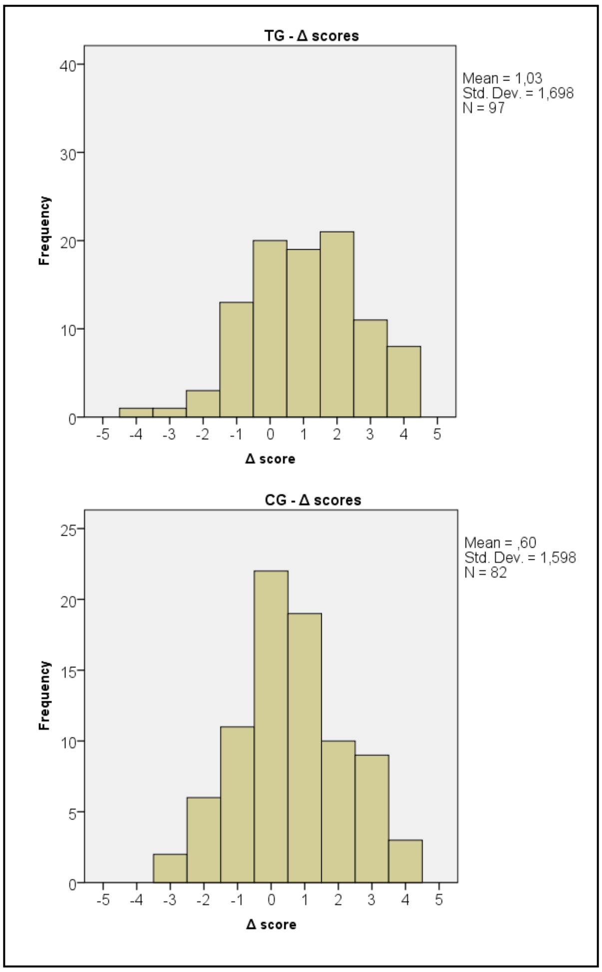

Figure 3. Δ score distributions of TG (top) and CG (down).

phonological skills. The training was administered to 97 first-graders from six classes of three different primary schools located in Torino (Italy). The design of the rhythmic tasks, which are part of a more extended training program, are presented. These tasks involve different rhythmic exercises, delivered via tablet and headphones to every child of each class, simultaneously. Improvements in rhythmic skills after the intervention period were compared with those of the matched control group of 82 first-graders, through pre- and post-tests based on rhythm perception and discrimination exercises. Analysis of the scores distributions of TG and CG, by applying the Mann-Whitney U test, suggests that the rhythmic training can have benefits for the development of rhythmic skills at the base of literacy and phonological awareness, as a much higher significance of pre- and post-test score distributions in TG (p-value=$4\cdot10^{-7}$) than in CG (p-value=0.012) and a significance of 0.10 between Δ score distributions of TG and CG were found. Nevertheless, a higher significance is needed in the future in order to corroborate and go beyond such preliminary results. Furthermore, cognitive and reading tests are currently under analysis in order to evaluate the effects of the training not only on the rhythmic skills themselves, but also on the phonological and reading skills of children compared to the CG. Such evaluation will also be performed through follow-up tests to evaluate the maintenance of the training benefits on a longer period. Further analysis will be also performed on children with scores below the 30th percentile in order to evaluate the effectiveness of the training on the subgroup of low performing children.

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