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Research Article

Reading Errors of Dyslexic Subjects after Rehabilitation with the Lexical and Sub-Lexical Method

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Abstract

Aim: This study evaluates the quantitative changes of reading and writing errors of dyslexic subjects after a rehabilitation program based on lexical and sub-lexical recognition of words.

Method: The treatment was divided in 3 cycles of 3 months each. 73 dyslexic subjects, from 6 to 13 years of age, diagnosed according to the DSM-5 criteria participated in the study. The direct test of reading and writing (DTRW) was used before and after treatment. The words were displayed for 250 m sec., "flash presentation", or for 10 sec., "sustained presentation". Wilcoxon for paired data and multiple linear regression tests have been used to estimate the outcomes of the treatment.

Results: The treatment shows a significant improvement of reading level, reading age, and reading quotient and of the number of words correctly read. Dysphonetic errors significantly decreased in both reading modalities, while the dyseidetic ones decreased significantly during sustained presentation. The program significantly improved the percentage of known and unknown words written correctly. Reading time was reduced by 20 ms and 69 ms during flash and sustained presentation respectively.

Interpretation: These results show that the method of lexical and sub-lexical recognition with perceptual masking increases the speed of visual and phonological processing.

WHAT THIS PAPER ADDS?

Systematic analysis of reading errors of dyslexic subjects after rehabilitation verification of Boder model applied in Italian dyslexic subjects an Italian test to identify dyslexia subtypes described by Boder.

In 1973, Boder claimed that reading is essentially a two-channel function, requiring the integration of intact visual and auditory processes both peripheral and central. It is essential for normal reading that these component processes go forward automatically. Based on this model, Boder and Jarrico (1982) [1] have developed a diagnostic screening procedure which identifies three main subtypes of dyslexia, dysphonetic, dyseidetic, mixed. The subtypes are identified by an algorithm that takes into account the reading quotient and the direct quantitative and qualitative analysis of the reading and writing errors. Individuals with dyslexia, according to Boder (1973) [2], commit reading and writing errors typical of the impaired cerebral structures, auditory or visual, classified as dysphonetic and dyseidetic errors respectively. An indirect confirmation of the validity of this model has come from the study of information processing time through cognitive brain potentials. It was shown that in dyslexic subjects a disproportionate asynchrony exists between the auditory and visual system in the cross-modal processing of auditory and visual information (Breznitz and Meyler, 2003, Žarić et al 2015) [3,4].

Chiarenza and Bindelli (2001) [5] have developed the Direct Test of Reading and Writing (DTRW), a computerized, modified and adapted version to the Italian language of the Boder test (Boder and Jarrico 1982) [1]. Luisi and

Ruggerini (1997) and Chiarenza and Di Pietro (2014) [6,7] have shown that these subtypes of dyslexia exist also in Italian speakers and have a percentage of distribution similar to that seen in dyslexics English-speaking subjects (Naiden and Winger 1972 personal communication, Ginn 1979 personal communication, cited by Boder and Jarrico 1982).

Although there is a vast literature on the processes that regulate reading, is still scarce the literature on the efficacy of rehabilitation treatments currently available in our country. Only in the last decade, several studies comparing different rehabilitation techniques were conducted to assess effectiveness and efficacy.

According to Tressoldi et al. [8], the rehabilitation treatment can be divided into three groups: 1) treatments effective both on speed and accuracy of reading: sub-lexical method [9], 2 treatments) effective only on the speed: Davis-Small treatment [10], treatment for the lexical development [11]; 3) other treatments: locomotor perceptual processing [12], generic linguistic treatment. The criterion for considering a treatment effective is its ability to reduce the gap between normal readers and dyslexic subjects both as regards the speed and accuracy of reading. This must happen faster than spontaneous evolution [13]. According to Tressoldi et al. [8], treatments based on automatization and lexical and sub-lexical recognition is effective both as regards speed, measured in syllables per second, and accuracy. The sub-lexical method according to Tressoldi et al. [14] would be more effective in outpatient settings than home, although the latter would increase the efficiency. In addition, the reading speed seems to increase significantly if more treatment cycles are completed [15]. The study of Iozzino et al. [9] confirms the effectiveness of sub-lexical method: the subjects treated by this rehabilitation program obtained on average, in about 220 days, an increase in reading speed of 0.5 sill / sec and commit fewer errors at the end of the treatment.

Iozzino et al. [10], stimulated by the psycholinguistic model of Geiger and Lettwin [16], presented a method of lexical and sub-lexical treatment to improve the speed and accuracy of reading in dyslexic subjects.

The objective of this research is to report the results of the quantitative and qualitative analysis of dysphonetic and dyseidetic errors after lexical and sub-lexical treatment. Since this treatment should have an impact on the direct (visual-Gestalt) and indirect (auditory-phonological) channel function, the hypothesis is that both dysphonetic and dyseidetic errors should decrease after the lexical and sub-lexical treatment.

METHOD

Participants

The sample consists of 73 subjects, 43 boys (58.9%) and 30 girls (41.1%) aged 8 to 14 years, average age 10.31 (S.D.1,78). 48 subjects (65.75%) were attending a primary school, 20 (27.40%) the secondary level and 5 (6.85%) a high school. Seventy children (95,89%) had never previously been subjected to speech therapy.

The clinical protocol for diagnosing dyslexia consisted of an anamnesis with the parents, a clinical interview with the child, a neurological examination, administration of WISC III, the MT-2 reading tests for primary school (Cornoldi and Colpo, 2011) [17], the MT reading tests for the secondary school [18], the battery for the assessment of dyslexia and developmental dysorthography [19], and the Direct test of Reading and Writing (Chiarenza and Bindelli, 2001) [5]. If from their history also emerged ifficulties in mathematics we proceeded to the administration of AC-MT battery [20,21] or the battery for the assessment of developmental dyscalculia (Biancardi et al. 2004) [22]. 18 subjects (24.6%) were suffering from dyscalculia.

All subjects had an IQ in the normal range (IQT= 105.14, SD: 12.95; IQV= 102.19, SD: 13.87; IQP= 106.48, SD: 11.88).

The diagnosis of dyslexia was made according to the DSM-5 criteria. Table 1 shows the results of the reading tests. All subjects had neurological examination results within normal limits (Table 1).

The direct test reading and writing (DTRW)

The DTRW is self-administered and self-paced (Chiarenza 2010) [23]. The DTRW consists of a reading and writing test. The reading test has 14 lists. The first four are

Table 1: Reports the results of the reading tests MT and DDE of the 73 dyslexic subjects.

Sill/sec (MT) Z score	Median	-1.32
	Mean	-1.30
	SD	0.81
Reading errors (MT) Z score	Median	0.91
	Mean	1.39
	SD	1.59
Sill/sec word, (DDE) Z score	Median	-1.42
	Mean	-1.36
	SD	0.63
Sill/sec non_word (DDE) Z score	Median	-1.25
	Mean	-1.03
	SD	1.18
Words errors (DDE) Z score	Median	1.31
	Mean	1.62
	SD	1.60
Non-words errors (DDE) Z score	Median	1.25
	Mean	1.47
	SD	1.32
Words reading time Z score (DDE)	Median	1.78
	Mean	1.94
	SD	1.80
Non-words reading time Z score (DDE)	Median	1.44
	Mean	1.77
	SD	2.15

for the first grade of the primary school, the other 10 for the other five classes, two for each attended class. Each list consists of 20 words each, ordered by increasing difficulty. The subject decides spontaneously when pressing a button with the dominant hand in order to display on a screen the word to be read. After pressing the word appeared for 250 ms, i.e. "flash presentation" mode, with the aim to evaluate the efficiency of the visual channel function. The instantaneous and correct reading aloud of a word indicates the presence of that word in the "sight vocabulary" of the subject. If words are not read or read incorrectly, the subject is asked to press again the button for displaying the word for 10 sec., "sustained presentation" mode, to investigate the auditory channel function. A microphone is applied to the subject who records the phonogram used to measure the reading time of each word.

The writing test, a direct result of the reading tests, consists of dictating to the subject two lists of ten words each: a list of known words, chosen from the "sight vocabulary", read correctly during "flash presentation", and a list of unknown words, chosen from those unread or incorrectly read during "sustained presentation".

At the end of the test the computer automatically provides the reading level (RL), which is given by the number of words of the last list from which the subject has read in "flash presentation" at least 50% of the presented words. Further the computer provides the reading age (RA), the reading quotient (RQ) given by the ratio between reading age and mental age, the number of words correctly read in flash presentation (NWCorF) and sustained presentation (NWCorS), the number of words read incorrectly in flash presentation (NWRIF), the average reading time of the words of each list read correctly in "flash presentation" (ARTWCorF) and in "sustained presentation" (ARTWCorS). Reading time means the time that elapses between the occurrence of the word on the screen and the start of the pronunciation of the word recorded through the phonogram.

The writing test provides the percentage of known words (KW) and unknown (UW) spelled correctly. Finally, the DTRW indicates the reading and writing pattern: dysphonetic, dyseidetic, mixed and residual. At the end of the administration of the test, the examiner scores all the errors. The most typical and frequent reading errors of dysphonetic dyslexia are: wild guesses, "gestalt errors" i.e. word substitution based on the similarity of the visual configuration and "semantic errors" i.e. word substitutions closely related conceptually but not phonetically. Typical and frequent errors of dyseidetic dyslexia are: confusion of visually similar graphemes, words containing the initial fragment, visual-spatial reversals of letters or syllables. The most frequent misspellings of dysphonetic subjects are: inclusion of letters, omission of syllables, substitution of graphemes, inversions of syllables, errors in the order of letters. The most frequent misspellings errors of dyseidetic subjects are: reversals of letters visually similar, visual-spatial reversals of letters and syllables. Double letters and accents errors, depending on whether they belong to the list of known or unknown words, are classified as dyseidetic and dysphonetic errors respectively. The classification of errors was conducted by three authors independently. When the classification of errors could be not univocal, the three researchers have subsequently reached an agreement.

Rehabilitation protocol

The lexical and sublexical treatment allows a chromatic scan of syllables or words to be read according to the reading speed based on the reading tests (Cornoldi and Colpo, 2012) [18]. The reading speed is set at the beginning of therapy and changed during the periodic controls according to the protocol described below.

The rehabilitation was done at home after the prior designation of a tutor. The subjects had to read a test for 15 minutes a day and 5 days a week. The choice of the lexical method or the sub-lexical one was done on the basis of the reading speed of words or non-words: the subjects who had a worse reading speed in reading words compared to that of non-words had to read word by word; the subjects who had a reading speed of non-words worse than that of words had to read syllable by syllable.

The therapy consisted of three cycles of three months each, each one followed by three months of pause. Treatment was concluded before the end of the third cycle when the subject reached a predetermined reading speed, or when the motivation and compliance of the subject and the family were scarce.

During each treatment cycle, the reading speed was controlled with the administration of MT test (Cornoldi and Colpo 2012) [18] at the beginning of the cycle, after a period of 1.5 months, at the end of the cycle, and at the end of the three months of pause for evaluating if the reading speed was maintained. The DTRW was administered at the beginning and at the end of the treatment: after one, two and three cycles.

Statistical analyses

Statistical analysis was conducted on the DTRW variables described above. As the number of lists of DTRW administered to the various subjects varied in relation to their basic reading skills and those acquired after treatment, all statistical analyses to assess the changes of writing reading skills after treatment were conducted on the same lists. The comparison of the DTRW results was conducted using the non-parametric Wilcoxon test for paired data. To test the effect of treatment a multiple linear regression was performed on the cycles of therapy. The verbal and the performance IQ were included in the multiple linear regressions as independent control variables, to assess the possible presence of other effects.

Therefore the effect of IQV and IQP will not be reported in the results but will be presented in Table 3. The multiple linear regression of the writing test was conducted in a subset composed of the subjects who had a percentage of known and unknown words spelled correctly of less than 70 %.

Due to the small number of the various types of errors in the writing test the statistical analysis of spelling errors was not conducted.

Statistical analyses were conducted on the combined cycles and on each cycle separately. The results of combined cycles are reported and when relevant for a better understanding of the data; results divided by cycles are also reported.

RESULTS

11 children (15.7%) completed the first cycle; 26 children (35.62%) 2 cycles and 36 children (49.32%) completed 3 cycles.

The DTRW test, identified the following pattern of dyslexia: 12 (44%) children had a simple reading retardation, 45 (61.64%) a dysphonetic dyslexia, 2 (2.74%) a dyseidetic dyslexia, 12 (16, 44%) a mixed dyslexia and 1 (1.37%) residual dyslexia.

The Wilcoxon test for paired data showed that all the DTRW variables significantly improved after treatment considering all the combined cycles together and separately, except the percentage of words read correctly in "sustained presentation"; this was significantly improved in subjects who performed 3 cycles of treatment (1 cycle: z = -0.85, p = 0.39; 2 cycles z = 0.68, p = 0.49; 3 z = 3,547 cycles, p = 0004). Table 2 shows the results of the comparison of DTRW variables before and after treatment (Table 2).

The Wilcoxon test for paired data on the writing test

Table 2: Reports the results of the comparison of TDRW variables before and after treatment.

DTRW: reading test		Treatment before after		Wilcoxon z	P<
NWCorF	Median	8	12	-12.03	0.0000
	Mean	8.18	11.80		
	SD	5.00	4.84		
NWRIF	Median	9	6	9.24	0.0000
	Mean	8.44	5.89		
	SD	4.52	3.86		
NWCorS	Median	.05385	0.5	1.42	0.1553
	Mean	0.51	0.49		
	SD	0.26	0.30		
ARTWCorF	Median	1.1	1.03	5.54	0.0000
	Mean	1.10	1.04		
	SD	0.35	0.27		
ARTWCorS	Median	1.61	1.36	6.45	0.0000
	Mean	1.75	1.39		
	SD	1.03	0.87		
RL	Median	2.3	3.55	-6.50	0.0000
	Mean	2.30	3.36		
	SD	1.31	1.27		
RQ	Median	76	82	-3.93	0.0001
	Mean	77.24	82.49		
	SD	14.68	16.04		
RA	Median	7.6	9.2	5.92	0.0001
	Mean	7.77	9.25		
	SD	1.64	1.34		
TDRW: writing test				**Wilcoxon z**	**P<**
KW	Median	50	80	-3.394	0.001
	Mean	50	73		
	SD	12.11	19.22		
UW	Median	50	60	-2.420	0.01
	Mean	45	53		
	SD	15.59	19.23		

Abbreviations: NWCorF=N° of words correctly read in flash presentation; NWRIF=N° of words incorrectly read in flash presentation; NWCorS=N° of words correctly read in sustained presentation; ARTWCorF = average reading time of words correctly read in flash presentation; ARTWCorS= average reading time of words correctly read in sustained presentation; RL=Reading Level; RQ=Reading Quotient; RA=Reading Age; KW= % Known words spelled correctly; UW= % Unknown words spelled correctly

before and after treatment shows that the percentage of known words spelled correctly increases significantly when considering the combined cycles together. The analysis conducted separately on cycles shows that this positive effect occurs only after two and three cycles (1 cycle: z = -1.41 p = 0.15; 2 cycles: z = -1.91, p = 0.05; 3 cycles: z = -2.47, p = 0.01). The percentage of unknown words spelled correctly increases significantly only after three treatment cycles (1 cycle: z = -0.61, p = 0.53; 2 cycles: z = -1.30, p = 0.19; 3 cycles: z = -1.84, p = 0.06).

Table (3) shows a summary of the multiple linear regression analysis on the subjects who have had one, two or three cycles of therapy. The reading level, the reading age of all subjects significantly improved, regardless of the number of cycles performed. The reading quotient improved significantly only after two and three treatment cycles.

The number of words read correctly in "flash presentation" significantly increased with treatment in all cycles. The percentage of words read correctly in "sustained presentation" did not vary significantly in the subjects who conducted one or two treatment cycles. Only the subjects who carried out three therapy cycles showed a significant decrease of the percentage of correct words.

The average reading time of words read correctly in "flash presentation" and in "sustained presentation" was reduced significantly only after a treatment of two and three cycles. The multiple linear regression analysis on the subjects who completed three cycles showed that the average reading time in "flash presentation" was reduced significantly by 20 ms, (SE: 0.03 t = -5.46, p <0.0001) and by 69 ms (SE 12.13 t = -5.31, p <0.0001)in "sustained presentation".

The percentage of known words spelled correctly increased significantly in patients who had two or three cycles of treatment. The percentage of the unknown words spelled correctly did not change significantly in all three cycles of treatment. The number of errors in the list

Table 3: Reports a summary of the multiple linear regression analyses to test the effect of treatment and IQs, verbal and performance (independent variables), on the DTRW variables (dependent variables).

		RA	RL	RQ	NWCorF	% NWCorP	ARTWCorF	ARTWCorS	KW	UW
Treatment 1° cycle	β	0.44***	0.39***	-0.10	3.05***	-0.05	0.09	0.00	15	2
	SE	0.11	0.12	2.57	0.56	0.05	0.04	0.18	15	3.74
	N	22	22	22	134	127	134	134	22	22
VIQ 1° cycle	β	0.00	0.00	-0.81***	0.02	-0.01	0.00	-0.03*	0.21	0.42
	SE	0.00	0.01	0.22	0.05	0.02	0.00	0.01	0.79	0.29
	N	22	22	22	134	127	134	134	22	22
PIQ 1° cycle	β	0.03***	0.04***	0.41	-0.11	0.01	-0.01	0.00	0.22	0.00
	SE	0.01	0.01	0.30	0.16	0.05	0.01	0.05	0.70	3.11
	N	22	22	22	134	127	134	134	22	22
Treatment 2° cycle	β	0.92***	0.73***	5.41***	3.98***	0.06	-0.16**	-0.64***	26***	2.68
	SE	0.21	0.18	2.08	0.47	0.04	0.05	0.11	7.48	6.29
	N	52	52	52	250	243	250	250	52	52
VIQ 2° cycle	β	-0.03	-0.03	-0.74***	-0.07	-0.01*	0.00	-0.01	-0.54	0.13
	SE	0.19	0.01	0.19	0.07	0.01	0.00	0.01	0.73	0.67
	N	52	52	52	250	243	250	250	52	52
PIQ 2° cycle	β	0.03***	0.03***	-0.14	0.17***	0.02	0.00	-0.01	0.57	0.54
	SE	0.01	0.00	0.11	0.05	0.04	0.00	0.01	0.55	0.34
	N	52	52	52	250	243	250	250	52	52
Treatment 3° cycle	β	1.56***	0.96***	5.05***	4.53***	-0.13***	-0.20***	-0.70***	20**	9.7
	SE	0.21	0.20	2.07	0.46	0.03	0.03	0.13	7.90	5.60
	N	72	72	72	215	215	215	215	72	72
VIQ 3° cycle	β	0.00	0.01	-0.21**	-0.06	0.05	0.00	0.00	-0.84	0.02
	SE	0.01	0.01	0.09	0.04	0.03	0.00	0.01	1.05	0.25
	N	72	72	72	215	215	215	215	72	72
PIQ 3° cycle	β	-0.01	-0.01	-0.51***	-0.08	-0.01	0.00	-0.04**	0.93	0.45
	SE	0.02	0.01	0.12	0.05	0.04	0.00	0.01	0.97	0.41
	N	72	72	72	215	215	215	215	72	72

Abbreviations: RA = Reading Age; RL= Reading Level; RQ = Reading Quotient; NWCorF = N° of words read correctly in Flash presentation; %NWCorP = Percentage of words read correctly in sustained presentation; ARTWCorF = average reading time of words correctly read in flash presentation; ARTWCorP = average reading time of words correctly read in sustained presentation; KW= Known Words spelled correctly; UW= Unknown Words spelled correctly. β= regression coefficient; SE= Standard Errors; N= Number of subjects for RA, RL, RQ, KW, UW. For NWCorF, ARTWCorF, ARTWCorP N= Number of read lists

***= p < 0.0001 **= p < 0.005 *= p < 0.05

of known words decreased significantly when all the set cycles were combined (z = 2.94, p = 0.003). This effect is not present in the list of unknown words (z = -1.36, p = 0.17) (Table 3).

Table (4) shows the results of the Wilcoxon test performed on the errors of the DTRW reading test before and after treatment. The analysis of the reading errors has shown that the total number of dysphonetic errors made during "flash presentation" mode decreased significantly in all treatment cycles. Wild guesses and non-words are reduced only after two and three cycles of treatment. Gestalt substitutions instead are significantly reduced after the first treatment cycle. The total number of dysphonetic errors made during "sustained presentation" significantly decreased only after two or three cycles of treatment. After two and three treatment cycles, for the improved reading skills in "flash presentation", the gestalt substitutions in sustained presentation are not sufficient to allow statistical analyses. Only the non-words are significantly reduced.

The total dyseidetic errors in "flash presentation" mode are reduced significantly after the first cycle and after three cycles. The words that contain only the initial fragment, typical error of the dyseidetic subject for his gestalt difficulties are reduced significantly, immediately after the first cycle. The lack of significance of other types of dyseidetic errors in "flash presentation" is mainly due to the small number of observations. The total number of dyseidetic errors and the number of non-words during "sustained presentation" decreased significantly after one and three treatment cycles. The lack of significance with two treatments cycles and of the other types of dyseidetic errors is due to the lack of sufficient observations (Table 4).

Table 4: Reports the comparison of reading errors before and after treatment.

Errors cycles		Number of errors before	after	Wilcoxon z	P<
Total numbers of dysphonetic errors in flash presentation	1	38	14	3.85	0.0001
	2	74	23	5.71	0.0001
	3	82	8	7.53	0.0001
Wild guesses	1	5	1	1.63	n.s
	2	15	2	3.17	0.001
	3	25	3	4.18,	0.0001
Non-words in flash presentation	1	25	13	2.19	0.02
	2	41	15	3.62	0.0003
	3	46	20	3.52	0.0004
Gestaltic Substitutions	1	33	9	3.88	0.0001
	2	64	21	5.13	0.0001
	3	79	6	7.82	0.0001
Total numbers of dysphonetic errors in sustained presentation	1	13	6	1.67	0.09
	2	22	7	2.77	0.005
	3	28	4	4.30	0.0001
Non-words in sustained presentation	1	8	4	1.15,	0.24
	2	16	5	2.41	0.01
	3	16	1	3.65	0.0001
Total numbers of dyseidetic errors in flash presentation	1	26	6	3.65	0.0001
	2	37	29	1.18	n.s
	3	35	19	2.25	0.02
Initial fragment in flash presentation	1	14	3	2.66,	0.007
	2	12	8	0.93,	n.s
	3	11	9	0.45	n.s
Total numbers of dyseidetic errors in sustained presentation	1	11	1	2.89,	0.003
	2	6	6	0.00	n.s
	3	13	0	3.60	0.0003
Non-words in sustained presentation	1	9	1	2.53	0.01
	2	3	3	0.00	n.s
	3	9	0	3	0.002

DISCUSSION

The DTRW shows that after treatment dyslexic subjects are able to read the most difficult list of words that they had never read before. The reading quotient (ratio of reading age and mental age) significantly improves after 2 treatment cycles (RQ: 77.2 before treatment and RQ: 82.4 after treatment). The reading age, however, significantly improves even after the first treatment cycle and increases of about one year and half going from 7.6 years to 9.2 years. There is also a significant increase in the number of words read correctly in "flash presentation" during all three treatment cycles. We cannot say the same for the percentage of correct words read in "sustained presentation": it is reduced significantly only after 3 cycles of treatment. A possible explanation of this result can be attributed to the fact that these words read are the most difficult to read even in "sustained presentation".

The total number of dysphonetic errors during "flash presentation" is reduced significantly after all treatment cycles, while those during "sustained presentation" decreased significantly only after the first two and three cycles of treatment.

The first dysphonetic errors that significantly decreased during "flash presentation" immediately after the first cycle are the gestalt substitutions, while the wild guesses and no-words are reduced only after two and three cycles of treatment. The dysphonetic errors that are significantly reduced only after 2 or 3 cycles of treatment during "sustained presentation" are the non-words. During this mode the dyslexic subjects do not commit anymore gestalt errors and wild guesses. The disappearance of these errors could be considered a good indicator of the achieved reading skills as, in the same span of word presentation time; the dyslexic child is able to implement a word analysis without having to resort to alternative strategies of visual type typical of a dysphonetic child. These observations may allow advancing the hypothesis that also the phonological

channel may benefit to this type of treatment. This could happen only after a certain period, perhaps only after the lexical channel has reached a higher degree of functionality and therefore an improvement in the processing of unknown words. Also the total of dyseidetic errors during the "flash presentation" and "sustained presentation" modes is reduced significantly after the first cycle and after three cycles. Among the dyseidetic errors that are reduced significantly, immediately after the first cycle, both in "flash presentation" and "sustained presentation" are the words that contain only the initial fragment, typical error of the dyseidetic subject that has difficulty with gestalt processing.

As it regards the writing test, statistically significant changes are noticed in the known words list, starting from the second cycle and for the unknown words after three cycles of treatment. Increasing the percentage of known words correctly written is an efficient index of gestalt processing. One of the main effects on the lexical channel function is to strengthen the visual memory and thus increase the ability to write the known words by accessing the visual lexicon without the phoneme-grapheme conversion. To similar conclusions arrived Gonzales et al. [24], who reported an improvement of reading after a training intensively focused on letter-speech sound mapping.

The increase, although not as high, of the percentage of unknown words is also indicative of a fairly efficient phonological channel function. The improvement of writing skills, although not directly treated, could confirm one of the operating assumptions of the Boder model (1973) [2] that states that reading and writing should be regarded as two "interdependent functions" and must be analysed "jointly". Therefore, the increase of the reading skills leads to a consequent improvement also of writing. Moreover, this improvement of writing skills, it is not due to a test re-test effect as the words used for the writing tests are different every time because they are chosen based on the reading level reached. Given the observational nature of this study, it could be argued that this treatment would mostly affect the lexical access of reading, improving the gestalt vision. This would lead to an improvement of the global recognition of words and probably expands the lexical "sight vocabulary" of the subject. On the other hand it cannot be excluded that other activities, in addition to training, such as studying music (Tierney et al. 2013) [25] to play specific games (Franceschini et al. 2013) [26], all activities affecting reading skills or even more simply the increased exposure to reading (as required by the training) have affected their reading skills (Cunningham and Stanovich, 1997) [27].

In any case, it is evident that the average reading time, i.e. the milliseconds needed to the subject to process the word since it appears on the screen, both in the "flash and sustained presentation" modes, are reduced respectively to 20 and 69 ms. These observations, not possible with common paper and pencil tests, could demonstrate that this treatment may modify the connectivity of brain networks related to reading processes, by increasing the visual processing speed of the word and also the phonological one after the second cycle. This observation is confirmed by recent psychophysiological studies that have investigated the changes of cognitive brain potential after reading acceleration program (Reading Acceleration Program, RAP) performed for 8 weeks (Breznitz et al. 2013; Horowitz and Breznitz-Kraus, 2014) [28,29]. The authors report that the RAP improves the reading speed, the processing time, visual memory, visual screening and reduces the number of errors in both normal and dyslexic subjects.

LIMITATIONS OF THE STUDY

These results even if they do not have a control group for the observational nature of the study, are in agreement with two preliminary reports which demonstrated the effectiveness of the lexical and sublexical treatment, comparing the reading speed of treated dyslexic subjects with that of untreated dyslexics and that of normal readers (Tressoldi et al. 2003) [8].

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