Visual and Auditory Attention Stimulator for Assisting Pedagogical Therapy

Ł. Kosikowski[1(✉)], A. Czyżewski[1], and A. Senderski[2]

[1] Multimedia Systems Department, Gdansk University of Technology, Gdansk, Poland
{kosiq,andcz}@sound.eti.pg.gda.pl
[2] Audiology and Phoniatrics Clinic, Children's Memorial Health Institute, Warsaw, Poland

Abstract. The stimulator system was designed to improve reading skills by displaying a combination of presentations and text in a visual form and in addition, transformed audio form which was shown alongside the relevant video material. The research described utilized a group of children (40 group participants) between the ages of 8–13 who displayed difficulties in reading or who were diagnosed with developmental dyslexia. The application showed that the proposed method improved the readings skills of the target group. By using the D2 attention exam implemented by R. Brickenkamp in its Polish form (created by E. Dajek) the effectiveness of this method was shown.

1 Introduction

During the learning process a child is focused on the reading technique and later concentrates in the literal meaning of the text. Later they move beyond the information and begin to analyze the content critically.

Visual function impairment within individuals creates confusion in letters displaying a similar shape and tend to ignore small graphic changes in addition to having difficulty in the synthesis of elements as a whole. Children with cross lateralization can also develop problems in reading.

Individuals who are voiceless or who suffer from auditory dysfunction are unable to distinguish between nasal sounds and have difficulty in specifying the consequence of that sound. The stated dysfunctions in the visual and auditory system cause significant problems when reading.

The process of visual learning is not homogenous and is a combination of many mechanisms and sub-systems which often possess different characteristics of function (Eysenck and Keane 2005); (Styrkowiec and Necka 2008). Visual attention is still a way of processing information and does not necessarily require higher mental functions.

Visual attention is still a way of processing information and does not necessarily require higher mental functions.

DOI 10.1007/978-3-319-62120-3_3

In cases of visual attention where particular focus is given to a certain part of the visual field selection mechanisms are assumed to work as follows (Eysenck and Keane 2005):

- Certain areas of the visual field have visual attention directed (Attention based on space)
- Objects located in the visual field have attention directed (Object based attention)
- Selection is made based on the locations or objects making the function of attention flexible

When considering FIT (Feature Integration Theory) - by (Styrkowiec and Necka 2008); (Tresiman and Gelade 1980) to be able to find an object in a specific location its special location is necessary to identify the object. Attention can be compared to a spotlight used by the brain based on the theory above. By scanning the environment for features such as shape and color it is able to link them to form a comprehensive whole. This is still the dominant theory which was described by Treisman and Gelade in 1980 (Tresiman and Gelade 1980). The visual part of the developed stimulator was based on this theory. To replicate the effect of a spotlight for the brain highlighted words force the user to focus on a specific area. Distractions located in the central view are reduced by excluding words appearing before or after the selected word. This facilities improvement on perceptions and additionally increases visual attention.

2 Stimulator Description

The main idea underlying the proposed stimulator is to perform parallel stimulation of the sight and hearing senses employing digital signal processing techniques. The modification of the visual and hearing stimuli is performed in order to force the perception through those senses by the appropriate hemisphere. Speech modification is obtained using non-uniform real-time speech stretching algorithm (Kupryjanow et al. 2013); (Kupryjanow and Czyzewski 2011).

Using a non-uniform real-time speech stretching algorithm speech modification can be obtained. Using various time scaling factors the TSM algorithm is able to modify in real time durations in various speech units. By using dedicated software, the proposed stimulation method was implemented. Headphones, an ordinary PC and an LCD monitor with the option of eye tracking software was utilized. Text accompanied by pre-recorded speech is displayed on screen using the basic operating mode while a lector reads the text aloud. The speech signal can be modified during playback (sped-up or slowed-down). Text presented on screen is accompanied by dynamic text highlighting which is synchronized with the speech signal. The text is synchronized with the speech by using LRC file format that typically synchronizes song lyrics with an audio file. As the reading progresses consecutive words or whole sentences can be highlighted. The operator can set the tempo of text reading or control can be made by the eye tracking system in a way that the eyesight of the user points towards a particular word. By using the appropriate adjustment of image parameters such as contrast, brightness, color and the size of the

letters the developed system allows for visual stimulation. Presented in Fig. 1. is a block diagram of the auditory visual attention training system.

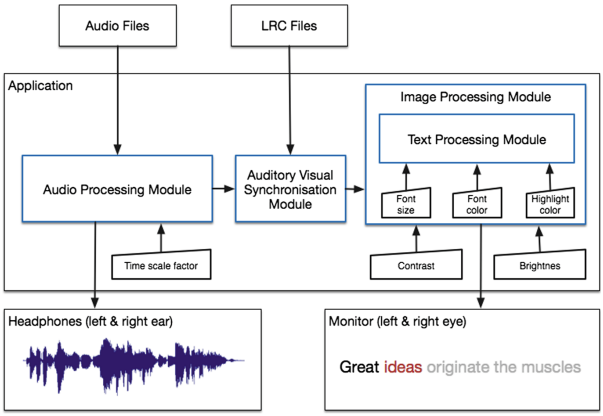

Fig. 1. Implemented training system

Designed around the principles listed above the role of the system is to support simultaneous listening and reading comprehension. By pressing a button on the keyboard a user is able to indicate whether he or she detects a difference in the audio heard (through headphones) compared to the highlighted text (displayed on a monitor).

By introducing similar and deliberate changes in the speech it allows the users attention to be checked. Audio-visual stimulation methods, aside from sensory stimulation, can also be used for training reading effectively. During a training scenario the same speech signal is sent to both ears simultaneously with the speech transcription highlighted (Kupryjanow et al. 2013).

3 Employed Study Subjects

By identifying 40 children between the ages of 8–13 with reading and learning difficulties and already diagnosed with developmental dyslexia the experiment was deployed. Candidates were selected from the clinic of psychological and pedagogical studies in Warsaw.

20 children were placed in experimental group E consisting of 11 boys and 9 girls. 15 boys and 5 girls were placed in control group C (Table 1).

Table 1. Age of examined children in individual groups

Group	Age of children [years]						
	8	9	10	11	12	13	Total
E	0	5	6	4	4	1	20
C	1	3	2	11	3	0	20
Total	1	8	8	15	7	1	40

Chi-square tests of independence were conducted for the data in Table 1. Null and alternative hypothesis in the test of independence are:

– Ho: The E and C groups are independent.
– Ha: The E and C groups are related.

In terms of the groups age it can be stated that no discrepancies are found based on results found in Table 2. Therefore, alternative hypothesis (Ha) can be rejected when comparing the relationship between the age of the group.

Table 2. Chi-square test analysis of age in groups

Statistics	Chi^2	df	p
Chi^2 – Pearson	7.909524	5	0.16129
Chi^2 – Max. likelihood	8.911232	5	0.11266

4 Methodology of Research

Using a host of different tests, the persons were examined. However, the paper focuses on the auditory perception, training of visual attention and the psychophysiology of visual perception.

4.1 Attention Analysis

Brickenkamp originally developed the applied D2 attention test. The Polish adaptation of the test created by Dajek E was used in this research (Brickenkamp 2003).

Initially designed to access the concentration of a driver and its suitability the D2 test was revised and renormalized in 2010. Concentration of the external visual stimuli is required for the test.

Based on the definition of attention the D2 test, according to the kind of selection and concentration, is aimed at achieving a small selection of stimuli.

The individual's ability to work without interruption is consequently verified along with their ability to correctly and quickly analyze relevant external or internal stimuli in a selective manner, without paying attention to stimuli that is irrelevant, is checked.

Three indicators were calculated based on the test results:

– WZ – Operating speed of examined person (total number of analyzed letters) evaluated
– %B – Mistake percentage (accuracy in work indicator)
– WZ-B – overall perception ability indicator (difference between total analyzed letters (WZ) and total error count (B)).

The results are presented and thoroughly analyzed in the next section.

4.2 Reading Aloud Analysis

Due to the different age of children, the two different reading aloud tests were used:

- Examining the disciples from classes 1–3 a test developed by Straburzyńska T., Śliwińska T. (Straburzynska and Sliwinska 1982).
- Examining the disciples from classes 4-6 and children in the 1st and 2nd grade of highschool a test developed by Sobolewska M. and Matuszewski A. (Sobolewska and Matuszewski 2002).

The reading speed, reading technique and reading accuracy (error count) were evaluated during the test. A word read rate of one word per minute was used in both tests. Normative values are analyzed from the obtained results and classified as low, average or high value.

Detailed results and analysis are presented in Sect. 5.

4.3 Research Procedure

The study has been launched after positive verification of the system by the Scientific Board of Memorial Health Institute.

Standard pedagogical therapy was subjected to the examined group. The visual and auditory attention stimulator supplemented therapy reading and writing exercises. Occupying 20–30% of the training time, exercises with the developed system was one hour per week. Only standard pedagogical therapy was treated to the control group. Only by using the stimulator were the groups distinguished.

The following procedures were performed before the test:

- Presented to parents was the purpose and methodology of the research.
- Before carrying out the test written and informed consent was given by the parents.
- A questionnaire on auditory processing disorder symptoms was completed by the parents.
- Hearing function was examined using:
  - Audiometry (tonal),
  - Impedance audiometry,
  - Central auditory processing tests: Speech understanding in noise test (aSPN); Pitch differentiation test (FPT); Assessment of interhemispheric integration mechanisms test (DDT),
- Included within the test were also children with normal vision, peripheral hearing and intelligence.

4.4 Training Utilizing Standard Pedagogical Therapy

Using visual and auditory materials effecting the mastery of writing and reading skills (eye-hand coordination and exercises under visual control) cognitive exercises were conducted as well as pictorial letter reading exercise material.

Aimed at improving: visual analysis, perceptivity, direction and visual memory exercises were of a visual function and spatial orientation.

An auditory function exercise aimed at enhancing: auditory attention, auditory sensitivity, auditory memory, sound differentiation (letter names - phones, ambient), phonemic and phonetic hearing (articulation, extracting, differentiation).

Combining letters into syllables and words the appropriate therapy was the practice of reading and writing on pictorial-letter material. The exercises focused on reading comprehension, reading literacy and rewriting efficiency by hearing and memory.

4.5 Training Using Designed System

As described above, all exercises and procedures for standard pedagogical therapy and additional stimulation using the system developed were applied.

To create and improve the many processes involved for teaching reading the auditory visual attention therapy was implemented. As a child reads the text appearing on screen they are able to listen to a reading denouncing this text at a slower rate and at the same time. Using a range of 2.0 to 1.3 the scale factor was adjusted individually to each child. Speech signals were reproduced to both ears simultaneously. During the therapy it was possible to adjust the scale factor meaning the end of the training reproduced text and voice at a faster rate than the beginning of the therapy. Adjustment and settings of font size and the separate coloring of words actually marked and for non-marked words is possible using the application.

Text displayed before being read by the lector was displayed in black. Either blue or red was chosen as a text color by the children. White or black was used for text that had already been read- white indicated the text was not visible after reading. During the first meeting font sizes and typefaces were selected. To permit the smoothest reading therapists were presented with several text options all of which were used after a few exams. Arial typeface was the most common choice.

For optimal initial training during the first months the scale factor was set to equal a value within the range of 1.2–1.3. The scale factor could then be modified in training to a value of 1.0 meaning a person achieved the ability to read with understanding and not requiring time-scale modification. Tailored to the student's abilities was the intensity and duration of the training.

The appropriate selection of text material, both the level of vocabulary and the content and degree of grammar difficulty was vital to the treatment.

The following procedure was performed after test completion:

- Symptoms of auditory processing disorder questionnaire completed by parents.
- Tests including aSPN, FPT and DDT were made in regards to central auditory processing.

5 Results

Using standard statistical methods, the data obtained during the study was entered into a database.

5.1 Preliminary Data Analysis (Before Pedagogical Therapy)

Normal distribution of variables assessment was carried out on the control group and experimental group in regards to auditory test results, survey results and in the D2 test and loud reading test before and after treatment using normality tests: Kolmogorov–Smirnov (KS test), Lilefors and Shapiro-Wilk

It was decided to apply the analysis of non-parametric tests based on these results.

The analysis of the d2 preliminary test result shows that experimental and control groups are similar to each other (see Table 3).

Table 3. Mann-Whitney Analysis for d2 test (Relative to variable: group). Statistically significant results for $p < 0,05$

Variable	Sum of the ranks E	Sum of the ranks C	p
WZ_WS $_{initial}$	387.0	433.0	0.542772
WZ_RP $_{initial}$	372.0	448.0	0.310017
B_WS $_{initial}$	475.0	345.0	0.080463
%B_WS $_{initial}$	461.5	358.0	0.167525
%B_RP $_{initial}$	386.5	433.5	0.519240
%B-Ranks $_{initial}$	393.0	427.0	0.612236

The groups were similar in terms of reading aloud test results except for number of syllables read correctly where the median in experimental group E was 75 and in control group C was equal to 127 (Table 4).

Table 4. Mann-Whitney Analysis for aloud reading test (Relative to variable: group). Statistically significant results for $p < 0,05$

Variable	Sum of the ranks E	Sum of the ranks C	p
WORDS_RAW $_{initial}$	372.0	448.0	0.314084
SYLS_RAW $_{initial}$	186.5	278.5	0.009064
WORDS_STEN $_{initial}$	370.5	449.5	0.288767
SYLS_STEN $_{initial}$	179.5	286.5	0.003321

The groups are similar to each other in terms of hearing test results- aSPN, DDT (right and left ear), and FPT (Table 5).

Table 5. Mann-Whitney Analysis for central auditory processing tests (Relative to variable: group). Statistically significant results for $p < 0,05$

Variable	Sum of the ranks E	Sum of the ranks C	p
aSPN $_{initial}$	409.0	371.0	0.809064
DDT_R $_{initial}$	407.5	372.5	0.843826
DDT_L $_{initial}$	439.0	341.0	0.278533
FPT $_{initial}$	371.0	370.0	1.000000

5.2 Analysis of Post-Therapeutic Results

Improvement in hearing tests within the experimental group and control group may be associated with both the positive effects of typical pedagogical therapy and the results of the effect of the auditory visual attention stimulator. The above results could be expected due to the exercises in the higher auditory functions were conducted on both groups during the therapy.

Test: D2

Experiencing more improvement both in terms of the number of scanned characters and a smaller amount of errors was group E. The changes observed relate to an improvement in the speed and accuracy of visual search and the increase in visual attention which has a direct impact on reading literacy.

In the experimental group (E) differences are observed in all parameters except %B_RP (see Table 6).

Table 6. Analysis of the results before and after therapy for E group and *d2* attention test. Wilcoxon signed-rank test. Statistically significant results are for $p < 0,05$

Pair of variables	N	p
$WZ\_WS_{initial}$ and WZ_WS_{final}	20	0.000089
$WZ\_RP_{initial}$ and WZ_RP_{final}	20	0.000089
$B\_WS_{initial}$ and B_WS_{final}	19	0.006211
$\%B\_WS_{initial}$ and $\%B\_WS_{final}$	20	0.017759
$\%B\_RP_{initial}$ and $\%B\_RP_{final}$	14	0.271948
$\%B\text{-}Ranks_{initial}$ and $\%B\text{-}Ranks_{final}$	10	0.021825
$WZ\_B_{initial}$ and WZ_B_{final}	20	0.000089

There is a difference in parameters WZ_WS and WZ_RP (percentage and raw score rank respectively) and WZ-B in control group C. Changes in the median are the following: WZ_WS from 350 to 399.5 and WZ_RP from 91.1 to 97.65. Those with a statistical significance increased in the number of characters perceived during the test without significant change in the number of errors at the same time as the WZ-B parameter changed from 339 to 368 due to growth in parameters WZ_WS and WZ-RP.

The attention test (D2) is focused accurately on testing the functions that the stimulator trains so the differences observed between study group E and control group C demonstrate the effectiveness of the therapeutic approach used. Moreover, observed changes in visual attention translate into reading performance as indicated prominently in the test results.

Test: Reading aloud

The results are comparable in both experimental group E and control group C as an improvement was observed. At the same time, this improvement was higher in experimental group E in regards to the number of syllables correctly read. This can only be interpreted as an effect of the visual attention stimulator.

Other parameters of experimental group E changed during the therapy but there was no difference in the before and after results for the parameter "Number of syllables read correctly" during the therapy (see Table 7).

Table 7. Analysis of results before and after therapy for E group and *reading aloud* test. Wilcoxon signed-rank test. Statistically significant results are for $p < 0,05$

Pair of variables	N	p
$WORDS\_RAW_{initial}$ and $WORDS\_RAW_{final}$	19	0.000214
$SYLS\_RAW_{initial}$ and $SYLS\_RAW_{final}$	15	0.002162
$WORDS\_STEN_{initial}$ and $WORDS\_STEN_{final}$	10	0.005062
$SYLS\_STEN_{initial}$ & $SYLS\_STEN_{final}$	7	0.017961
$SYLS\_Err_{initial}$ and $SYLS\_Err_{final}$	14	0.451260

For control group C parameters "The number of words read correctly" and "The number of syllables read correctly" there is no difference before or after therapy while other parameters changed during the therapy.

It is indicated that changes in both groups can be compared with the exception of parameter "The number of syllables read correctly" as the median increases in the experimental group and the control group to 26 and 15.

However, after excluding from the counting the subjects reading the entire word, prior to therapy, for the experimental group, the median value changed from 75 to 100 and for the control group, the median value changed from 105 to 112.

Test: Central auditory processing

Statistically significant improvements were observed in both experimental and control group in the results of the following tests: DDT (left ear), FPT, and aSPN. In the experimental and in the control group there were no statistically significant changes only for DDT test for the right ear.

In the case of the experimental group (E) the median amount increases for particular tests (see Table 8) as follows:

- Assessment of interhemispheric integration mechanisms test (DDT) for left ear increased from 57.5% to 70%.
- For pitch differentiation test (FPT) from 60% to 80%.
- The median changed from 2 dB to −1 dB for the speech understanding in noise test (aSPN).

Table 8. Analysis of results before and after therapy for E group and *central auditory processing tests*. Wilcoxon signed-rank test. Statistically significant results are for $p < 0,05$

Pair of variables	N	p
$aSPN_{initial}$ & $aSPN_{final}$	16	0.012454
$DDT\_R_{initial}$ & DDT_R_{final}	17	0.758313
$DDT\_L_{initial}$ & DDT_L_{final}	20	0.003185
$FPT_{initial}$ & FPT_{final}	19	0.000214

The median increases for particular tests for group C as follows:

- DDT for left ear, from 52.5% to 68.7%.
- FPT from 62.5% to 75%.
- aSPN from 62.5% to 75%.

Based on the context of results of the above test it can be assumed that a better therapeutic effect might be observed after prolonged therapy.

6 Conclusions

Large rendered fonts are preferred for reading by individuals with dyslexia. Children displaying a difficulty in attention do not often follow the text shown on screen. Texts should be differentiated and tailored to individual students reading levels for this reason.

Proposed candidates designated for therapy maybe be children with difficulties in reading or learning. Children with developmental dyslexia or deep dyslexia associated with other disorders can support standard school activities using the developed tool. Pedagogical therapies may also be assisted using this tool.

Additional correcting and the consistent development of children abilities are allowed by some features of the proposed system, in particular cases of children with varying impairments including dyslexia or cross- dominance.

This system of training can also be used for the effected learning of language due to the time required for learning being much shorter and the signal of speech being more understandable. By using additional visual modality? the proposed system also extends the typical lateralization of training solutions. The proposed approach does not require any additional hardware extensions in its basic form in contrast to the Dirk Bakker method (Backer and Satz 1970).

Acknowledgment. Research started within the project No. POIG.01.03.01-22-017/08, subsidized by the European regional development fund and by the Polish State budget and continued within the project funded by the National Science Centre allocated on the basis of the decision DEC-2014/15/B/ST7/04724.

References

Bakker, D.J., Satz, P.: Specific Reading Disability. Advances in Theory and Method. Rotterdam University Press, Rotterdam (1970)

Brickenkamp, R.: D2 Test. Attention test. Manual. ERDA, Warszawa (2003). (in Polish)

Eysenck, M.W., Keane, M.: Cognitive Psychology. A Student's Handbook. Psychology Press, Hove (2005)

Kupryjanow, A., Czyzewski, A.: A method of real-time non-uniform speech stretching. In: ICETE 2011. CCIS, vol. 314, pp. 362–373. Springer, Heidelberg (2012)

Kupryjanow, A., Kosikowski, L., Odya, P., Czyzewski, A: Auditory-visual attention stimulator. In: 134th AES Convention, Rome, Preprint no 8810 (2013)

Sobolewska, M., Matuszewski, A.: Test of Reading Aloud. Manual. CMPPP, Warszawa (2002)

Straburzyńska, T., Sliwinska, T.: Series of Reading and Writing Tests for 1–3 Class of Primary School. COMPW-ZMEN, Warszawa (1982). (in Polish)
Styrkowiec, P., Necka, E.: About two systems of visual attention. Przegląd Psychologiczny, TOM 51, Nr 2, pp. 113–133 (2008). (in Polish)
Tresiman, A.M., Gelade, G.: A feature-integration theory of attention. Cogn. Psychol. **12**, 97–136 (1980)