Reader™

Introduction to a Reading Remediation Technology

A White Paper

Revised October 2011

www.brightstar–learning.com

BrightStar learning Ltd., Jerusalem Technology Park

Jerusalem 96951

Abstract

Reader is a novel, patented remediation method for ameliorating reading difficulties (slow and reluctant readers) and learning disabilities such as dyslexia. The early non-internet Reader, the version discussed in this white paper, utilizes a unique combination of technology – an offline PC, scientifically-designed perceptual-sensory-motor training software, proprietary correlation algorithms timing the generated stimuli to the user's physiological activity, and personalized remedial teaching training – to provide a viable, integrated solution to learning disabilities. Reader has since been advanced to use the Internet and World Wide Web in order to provide the remediation to as large an audience as possible. Reader effectively trains the user's eye movements and attentional processes, resulting in measurable improvements in reading performance.

Study findings and hundreds of satisfied Readers clients demonstrate compelling evidence of Reader's effectiveness. An independent research study of adults conducted in the United Kingdom showed statistically significant increases in word recognition and naming speed as a result of Reader training. Results from standardized clinical assessment tests in children showed statistically significant improvements in four measures of standardized average age-equivalence scores (compared to pre-training assessments):

1. **Twelve months** improvement for **Neale reading comprehension** ($p < 0.001$);
2. **Seven months** improvement for **Neale reading accuracy** ($p < 0.001$);
3. **Eleven months** improvement for **Helen-Arkell spelling** ($p < 0.0001$), and;
4. **Eighteen months** improvement for **WordChain word recognition** ($p < 0.0001$).

Since 2003, over 2,000 individuals from the United Kingdom, Holland and the United States have used Reader with positive results. In comparison to other kinds of remedial training, Reader technology outperforms literacy gains in normal schooling by **six** times and outperforms specialized schooling for dyslexics by over **four** times. The Reader program is an effective option for improving reading skills.

Table of Contents

Introduction

Today there is an ever increasing emphasis on information that must be read, particularly for our children as they grow up in an electronic world. Unfortunately, the world's most common learning disability, dyslexia – difficulty with reading and spelling – affects ten to fifteen percent of the population[1]. Both children and adults with dyslexia are not able to keep up with their peers. Besides the personal struggles that arise from dyslexia, these pervasive reading deficits ultimately create a significant social problem, particularly in our fast-moving world that emphasizes visual information. Over fifteen billion dollars are spent annually in the U.S. to help children with learning disabilities[1,2]. Reader is a unique computer technology designed to ameliorate reading difficulties (slow & reluctant readers) and reading disabilities such as dyslexia. This paper presents an in-depth look at the science behind the Reader technology and discusses how Reader enhances the ability of children and adults to significantly improve their reading abilities.

Reader

After decades of research, the founders and scientists of BrightStar Learning developed a proprietary technology[3,4] called Reader. This proprietary technology uses a unique combination of three components: a personal computer, non-verbal sensory motor training software and proprietary synthetic algorithms that correlate the visual stimuli to the user's ongoing physiological activity. The technology provides an effective method to ameliorate reading difficulties (e.g. slow and reluctant readers) enhancing reading performance and reading disabilities, in particular dyslexia.

Reader's first component is a personal computer. The user sits in front of a computer screen and does the following two successive functions for specific periods of time: passively gazes at the dynamic display and interacts with the computer via a mouse during real-time training. The technology is calibrated and quality tested to ensure the precision, timing, control, and depth of sensory motor training required.

The second component is scientifically designed, non-verbal training software. BrightStar's scientists and software engineers applied years of contemporary research and findings in psychology, physiology, physics, and neurobiology in developing Reader. The user focuses on performing a mild-cognitive task that involves psychomotor tracking. The task may look simple but its performance requires continuous sustained attention and involves complex motor coordination of the eyes and hand.

The user attempts to maneuver a target (e.g. a car) along a simple winding moving path. The accuracy of the user's navigation of the target (navigation accuracy) is measured. The navigation task appears in the center portion of the computer screen, corresponding to the user's central visual field. This visual display is not as exciting as an elaborate video game, quite the contrary, Reader's interactive sensory motor technology consists of a quasi-monotonous game-like exercise scientifically designed to train the client to visually allocate his focus attention on the task at-hand and ignore distractions in the periphery visual display. Over the course of the 12-minute sessions, this activity strengthens the user's ability to receive detailed information through the visual system.

Concurrent with the images and activities in the center of the screen, Reader controls a second outer area on the computer screen, corresponding to the user's peripheral visual field. In a sense, this is a distraction field. Random and quasi-random events take place to provide a special kind of distraction to the user. These distractions are scientifically designed to interfere with the performance of the pursuit task in a correlated way. The software targets biological interactions between the user's spatial attention and the eye tracking skills used to control the complex eye movements involved in reading.

While the user's fovea, the center part of the retina with a high concentration of cones, is focused on the center portion of the Reader screen, the peripheral part of the retina, which contains a higher concentration of rods, is being triggered by the visual stimuli. The visual stimuli take the form of sprites (chains of illuminated pixels) moving across the visual display at different speeds and blinking from time to time. These sprites activate the user's visual system and strengthen the aptitude of visual motion information flow from the retina's periphery to the correct areas of a user's brain. The proper channeling of visual motion information in the brain helps to guide proper eye movements without diverting attention from the central visual field, which in turn benefits three key reading areas with which dyslexics often struggle: decoding words, reading next words, line-to-line tracking.

The peripheral visual field distractions are timed through the third component of Reader's non-verbal technology: proprietary synthetic algorithms that correlate the visual stimuli display to the user's ongoing physiological activity. For over fifty years scientific literature has demonstrated that mind and body processes are closely coupled. With particular reference to attention and reading, the way the heart responds, is particularly important. Heart rhythm is directly coupled to the brain[5]. Widely known to researchers and to anyone who has experienced a sudden unexpected "stimulus", the heart will change its beat.

This reaction to sudden stimuli, referred to as 'orienting', is taken into account in Reader's proprietary synthetic algorithms. User orientation is accomplished by synthetically correlating properties of the generated visual stimuli to particular phase(s) of a chosen physiological activity. Thus, the Reader technology is not simply a video game activity with physiological interaction, but rather it is a neuro-performance technology.

Something very interesting happens when events in the peripheral visual field are temporally coupled to bodily responses while performing a mildly demanding psychomotor task. This type of training does not normally occur in everyday life, yet it has a subtle and long lasting effect on the way a person uses attention for improved eye-movement coordination, such as in reading and other cognitive tasks. A child or an adult using Reader's neuro-performance technology is unaware of the special timing of effects. The scientifically based software generates stimuli outside of the individual's awareness. In a sense, it implicitly teases the user's nervous system to "play" in an optimal way.

Children and adults commonly report that they do not think anything else is going on during the sessions except their attempt to perform well the psychomotor task. The entire process of making complex eye movement behavior become more efficient involves brain processes we are not aware of. It takes time until it becomes automated, the same way as learning any other complex motor task, such as riding a bicycle or skiing. Only after a number of Reader sessions, usually over three weeks of training, users sense that something else is happening: they have an inkling of becoming more self-aware and "getting it". In fact, this anecdote is common from clients after all their sessions are complete. Even more interesting than being able to read faster and comprehend more, many users report being more "tuned in", thinking faster, and just plain "getting it" better. Some even claim to notice an improvement in other activities, such as tennis, ping-pong, driving, and playing poker.

While we make no scientific claims in relation to these ancillary improvements, it does make sense that improved peripheral vision, improved ability to focus, and improved processing and pattern recognition can strengthen the ability to perform these activities and others.

A typical Reader training regime lasts six weeks and consists of two 12-minute sessions a week. In addition, standardized testing of reading skills is done before and after the training regime. The standardized testing is used to quantitatively assess the initial level of performance on a set of reading and comprehension tests and on the improvements following the training regime.

By design, the Reader neuro-performance technology has a positive effect on attention shifting and allocation and reading. In the next section, the results that are typically obtained through Reader non-verbal sensory motor training are discussed.

Reader Training: Evidence for a Real Effect

During the years 2004 and 2005, Reader sensory motor training regime comprised of three phases. The first phase was a pre-training assessment which incorporated standardized testing on several key measures of reading. The second phase of Reader training consisted of a six-week series of two weekly 18-minute long sessions and one tutoring session for children. For adults the tutoring session was not required. The third phase was a post-training assessment, again using the standardized testing measures. Improvement was then quantified by the difference between pre-training and post-training scores. Evidence of improvement was found in several studies, some carried out by universities and others internally.

Several studies carried out in the years 2003-2005 provide concrete evidence of improvement as a result of use of early non-internet Reader technology. Researchers at the University of Nottingham conducted a single-blind independent research study of 38 adults, 16 to 60 years old, comparing Reader to a control group. The Reader group improved their **word recognition** and **naming speed** significantly more than the control group[6]. These statistically significant results suggest that Reader targets the underlying perceptual difficulties in dyslexia and enhances word recognition and fluency with a net improvement in reading performance.

Additional evidence comes from the company's proprietary BrightStar learning centers. Reader has been offered through BrightStar learning centers in the United Kingdom since 2003. Findings obtained from users at these centers were presented at the annual conference of the British Dyslexia Association[7] (BDA). Another BrightStar white paper – "Reader Performance" - describes the study results of user improvement in greater detail[8]. One way of gauging increases in performance is to scale improvement in the context of the gains that a statistically normal child - one without symptoms of dyslexia - would make over time. A statistically normal child improves reading performance merely as a function of experience (i.e., a month’s gain for a month’s time at a particular age). This measurement is called an age-equivalence score. Post-Reader sensory motor training assessments showed very high, statistically significant improvements in four measures of standardized average age-equivalence scores (when compared to pre-training assessments):

- **Twelve months** improvement for **Neale reading comprehension** ($p < 0.001$)

- **Seven months** improvement for **Neale reading accuracy** ($p < 0.001$);
- **Eleven months** improvement for **Helen-Arkell spelling** ($p < 0.0001$); and
- **Eighteen months** improvement for **WordChain word recognition** ($p < 0.0001$)

For those unfamiliar with these statistical terms, “p < 0.0001” means that the probability that the results happened by chance are 0.01%. Or in other words, there is a 99.99% certainty that the results achieved are due to a real change caused by Reader technology. The widely-accepted cut-off for valid statistical measurements is p<0.05 (95%), so these measurements of p<0.001 (99.9%) or p<0.0001 (99.99%) are highly significant.

These results become even more meaningful when one considers that the Reader training regime is only six weeks long. An additional internal study of 412 Reader users between the years 2003-2004, show similarly impressive results[9]. The UK assessment procedures, data collection and reporting were validated by PricewaterhouseCoopers in 2004[10]. Similarly impressive results were found with users in the United States during the years 2004-2005 and in Holland during the years 2009-2010. Post-Reader assessments demonstrated significant improvements in four measures of standardized average age-equivalence scores (when compared to pre-training assessments):

1. **Twenty months** improvement in **Woodcock Reading Mastery Test** (WRMT) **passage comprehension** ($p < 0.025$);
2. **Thirteen months** improvement in **WRMT non-word reading** ($p < 0.001$);
3. **Ten months** improvement in **WRMT word recognition** ($p = 0.025$), and;
4. **Eight months** improvement in **Woodcock-Johnson III (WJIII) reading fluency** ($p < 0.001$).

Another way to look at the improvements shown in the UK data is to put them in perspective with other methods of training or teaching. If one considers that the four standardized reading performance tests are statistically independent, one can then combine them into one total score. The gains made through normal schooling would amount to an equivalent total score of one by adding up the scores of the four performance tests. This ratio would reflect a normal amount of improvement in reading performance as a function of time; one-year improvement in reading performance for a year of schooling. This improvement is represented in the “non-Dyslexic with normal teaching” column in Figure 1. Dyslexics with normal teaching, that is, children in a normal school with no special education teaching, tend to fall behind; they gain an increase of approximately one-half of a year in reading performance for one year of schooling, as shown by column two in the Figure 1. Dyslexics usually fall behind year after year in normal schools without special instruction. Thus, the actual "falling behind" is compounded yearly. In the US and UK, there are specialized schools for dyslexics – they show an equivalent gain of 1.5 years increase in reading performance for each one year of special schooling. In contrast, the total gains from Reader (twelve sessions) amount to approximately **six** times that which is accomplished under normal schooling and over **four** times the performance increases found in specialized schooling for dyslexics. These results will be discussed in the next section.

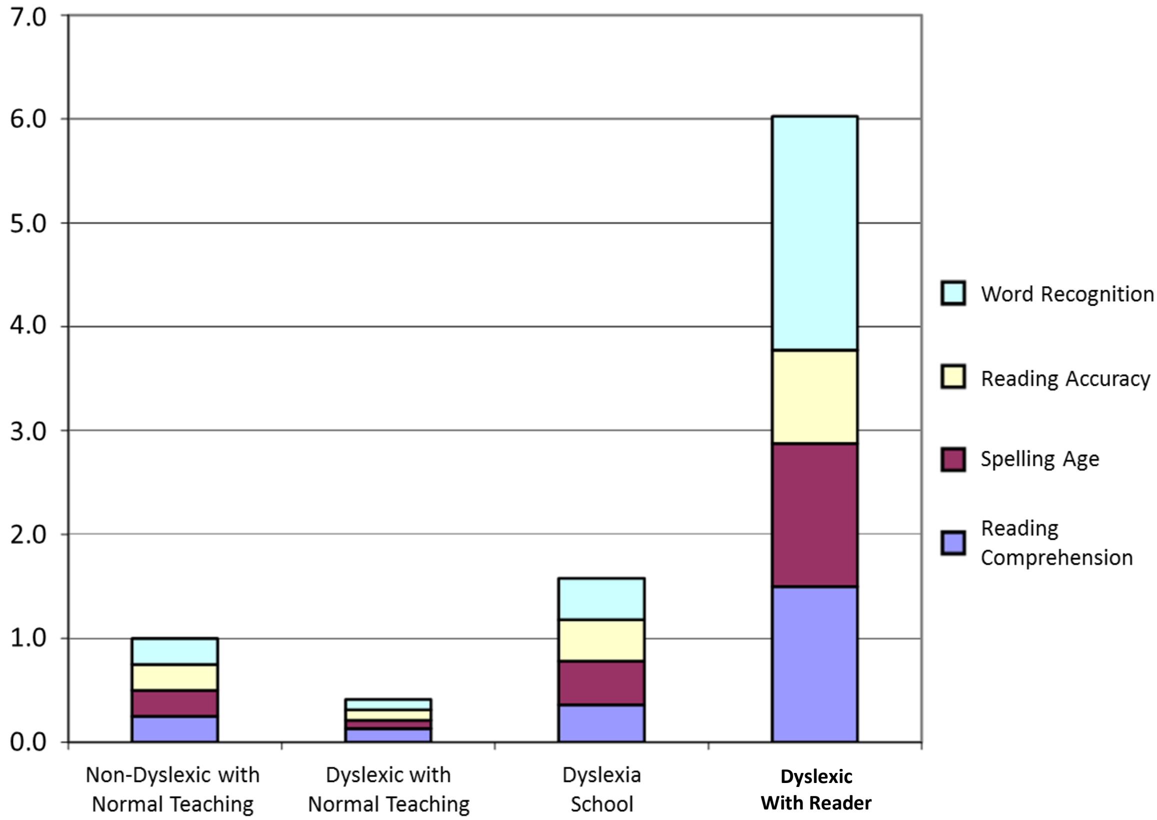

Figure 1: Combined Performance Improvement by Teaching Method

A Deeper Look at Dyslexia

The Reader technology is an effective option for the over 30 million Americans who are dyslexic, most of whom demonstrate an obvious struggle with reading[11]. Reading has become an integral part of our daily lives and our educational system, and is a primary source for learning new information[12]. Difficulties with reading can make schooling very difficult and can lower self-esteem when the child falls significantly behind his peers[1].

This difficulty in reading can be related to problems in two primary processes: a quick, holistic recognition of the written word, and a slower translation of the written word to sounds[13]. Both of these reading processes can be inaccurate or slow, which can lead to difficult or imprecise reading[12].

Difficulty in reading can be attributed, in part, to difficulty with an initial, fast process. This process of quick, holistic word recognition is an early phase of reading that involves parsing the visual flow of information into conceptual chunks. The translation of written words into sounds we recognize is a second non-trivial process. This second process, also known as phonological (letters and sounds) awareness, requires the parsing of a word into its letters and syllables and making the subsequent association between the two[14]. It is through this process that we can sound out unfamiliar words or pronounce words we have never seen before. Many people find this process difficult and it impedes their ability to read fluently[14]. This difficulty appears to be an innate neurobiological deficit in dyslexics[14].

Definition of Dyslexia

The International Dyslexia Association (IDA)[1] has constructed a definition of dyslexia that emphasizes its underlying causes and symptoms:

> "Dyslexia is a specific learning disability that is neurological in origin. It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge." [16]

This definition provides a useful framework from which to discuss the reading difficulties associated with dyslexia. Reading difficulties can be divided into four basic phases: a neurobiological origin phase, a phonological (sound of words) phase, a recognition and decoding phase, and a comprehension phase. These four phases are represented in Figure 2.

Figure 2: The International Dyslexia Association[1] Model of Dyslexia from Origin to Symptoms

The neurobiological origin phase suggests that early developmental bottom-up sensory-motor-perceptual functions, cerebellar control of eye movements and attention mechanisms facilitating orienting towards sudden stimuli, influence the transmission of visual information into higher structures in the brain and may be at the root of reading difficulties and dyslexia. The translation of visual information into the sounds of words is impeded, creating a phonological deficit. This phonological deficit leads to difficulties in word recognition and decoding, which in turn leads to problems with reading comprehension, an underdeveloped vocabulary, and less reading experience. According to the IDA definition, the cause of these difficulties is a deficit in the phonological component of language. Recognizing words, and therefore reading, is made more difficult by this word-into-sounds deficit. Not surprisingly, phonological ability is the strongest and most specific predictor of reading ability[15]. The latter three phases of the model of dyslexia follow from a neurological deficit that sets the stage for the unique characteristics of dyslexia.

The Origin of Dyslexia

"Neurobiological origin" from the IDA definition suggests that structures in the body, particularly the brain, are at the root of learning disorders. Recent scientific research suggests two differences at the neurobiological level in dyslexia. One line of research suggests that reading and spelling difficulties experienced by dyslexics occur due to perceptual deficits in the visual representation of the position of letters in a word[16]. Another line of research suggests that motor areas of the brain influence the reading process[17]. This latter avenue links deficits in the control of eye movements and automation of tasks to reading. Normal control of eye movements is critical to reading[18]. In normal reading, the eyes move approximately three times a second[19].

The stepped sequence involves quasi-stopping to fixate on a set of words for recognition, then moving to the next set, until a line is completed. This complex behavior not only involves proper eye positioning, but also proper flow of visual information through the brain. Precise eye movements must be in concert, moving smoothly over a line of text, then down to the next line. This movement also requires a sustained focus of attention without shifting the eyes to other distractions. Normal sustained control of eye movement leads to consistent flow of visual information and promotes the perception and recognition of words and letters[20]. The consistent flow of words can then be translated into the phonetic sounds of language. A lack of effective control of vision can impede the phonological "sound of words" awareness, thus reducing reading accuracy and reading fluency[20].

For a dyslexic, a scanned line of text (resulting from deficient eye movement control) might look like a string of words correctly registered at the beginning and end, but poorly in-between; this might appear as in the following figure (see Figure 3).

Figure 3: Example of What a Dyslexic Might See While Reading[20]

One theory of dyslexia suggests that dyslexics' problems with reading, word recognition, and spelling are due to deficits in a certain visual pathway of the brain[18]. This particular visual neural pathway responds preferentially to rapidly (also slow) changing visual stimuli[18]. The neurons in this pathway respond quickly to visual stimuli, making it an effective system to detect motion, particularly in the peripheral visual field. This motion detection ability is imperative to reading – as the eyes move across a line of text, the next eye movements must be properly planned to ensure continuity of smooth movement along the line. Word recognition becomes easier and more fluid if the visual system is processing the words as they move quickly across the retina. The information from this visual pathway provides the basis for word recognition and how the eyes will move next. Fluent reading depends on the efficient perception and processing of visual information.

There is considerable evidence concerning the responsiveness of this particular visual system in dyslexics. For example, research has demonstrated that dyslexics are less sensitive to visual motion[18]. Dyslexics are less perceptive of a coherent group of dots moving in a larger group of randomly moving dots.

The ability to differentiate spatial frequency is also impaired in dyslexics[19]. The perception of contrast is impaired in dyslexics at low spatial and high temporal frequencies. Taken together, these two differences in the dyslexics' visual pathway can create difficulties recognizing and decoding words as our eyes quickly move across a page of text.

The Cerebellum

There is yet another part of the brain that is involved in this process. Anatomically, the dorsal pathway that serves visual motion, sends this information to the cerebellum, an important motor area of the brain[17] (see Figure 4 for anatomical location). The cerebellum is more commonly known for balance and (muscle) motor control of complex behavior.

Dysfunctions in the cerebellum can explain handwriting, clumsiness, and balance difficulties[17]. But the cerebellum also controls the timing of eye movements and automating these movements while reading – two important aspects of reading.

Eye movement is usually beyond an individual's conscious control, in much the same way as the ability to maintain balance during walking. The cerebellum uses information from the visual system to coordinate the eye muscles involved in reading[21].

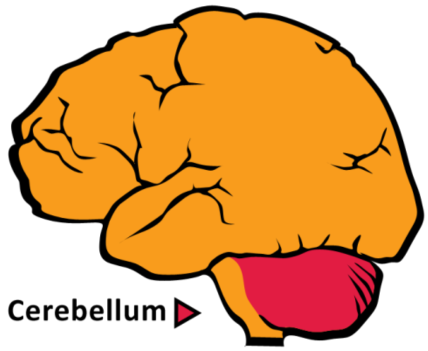

Figure 4: Location of the Cerebellum Shown in a Left Side View of the Human Brain

The cerebellum is also important for automating movements[22]. As a child learns how to walk, the cerebellum is involved in learning the patterns of movement. The process of learning becomes automated, that is outside normal conscious awareness, after an extended period of days to weeks of practice. After this learning period, walking requires almost no attention and little conscious thought. Reading, a more complicated process than walking, depends in part on eye movements; it is a skill that requires more practice to become automated. Moreover, with a dysfunctional cerebellum, reading may not become completely automated and may require more attention effort[22].

Cerebellar function in dyslexics is not as efficient when compared to normal brain function. In a brain imaging study, dyslexic adults showed only 10% of the cerebellar activity of non-dyslexics while executing new movement-related tasks[23]. This implies that the cerebellum is not functioning sufficiently in dyslexics.

The cerebellum is also partly responsible for speech articulation[24]. If speech is not correctly articulated, phonological awareness can suffer[24]. Without proper representations of speech sounds, the mappings of letters to their corresponding speech sounds will be less accurate, reducing reading accuracy.

Thus, the cerebellum has a profound effect on reading development through automated eye movements, skill learning, and phonological awareness[17]. The cerebellum is part of the neurobiological basis of dyslexia — and it can be influenced. Under special controlled conditions the cerebellum can be trained to provide better automated control of eye movements and sustained attention. These special controlled conditions are integrated into the Reader Technology.

Discussion and Conclusion

Reader technology results in improvements in reading performance that are statistically significant. Several studies have demonstrated that reading comprehension, reading accuracy, spelling and word recognition scores show statistically significant and consistent increases after use of Reader. When these improvements are put into perspective, Reader has a cumulative effect six times normal schooling in non-dyslexics, twelve times the effect with normal schooling in dyslexics, and four times the effect of dyslexic schooling.

Reading performance is significantly increased in contrast to other methods. However, the greater than six-fold increase with respect to normal advancement must be taken in context. Remember, dyslexics fall behind year after year. In a way, it is similar to compounding annual interest, although it is a deficit that is compounded in this context. The implications of this are that Reader promotes neuroplasticity changes on transient neural circuits (magnocells) that grant the dyslexic a consistent flow of visual motion information. Dorsal magnocellular flow that reaches the cerebellum, communicates information to motor neurons attached to the eyes' muscles that effectively control the involuntary timely execution of eye movements.

Reader is an enabling technology that provides the means to catch up with normal (age adjusted) advances in reading performance, thereby reducing the deficit. We theorize that in order to guarantee long term effects of Reader it needs to be followed by remedial teaching strategies. The combination of Reader assistive technology and phonological remedial teaching strategies - specifically pinpointed on phonological decoding - hopefully brings the user closer to a level of performance in line with his normal peer group.

References

1. www.interdys.org

2. US Dept. of Education, Special Education Expenditure Project, 2000. Excludes regular education expenditure on SLD children.

3. Kullok, S., and Kullok J. Apparatus, Method And Computer Program Product To Produce Or Direct Movements In Synergic Timed Correlation With Physiological Activity. Patent No. US 6,644,976 B2. 11 Nov 2003. United States Patent and Trademark Office.

4. Kullok, S., and Kullok J. R. Apparatus, Method And Computer Program Product To Facilitate Ordinary Visual Perception Via An Early Perceptual-Motor Extraction Of Relational Information From A Light Stimuli Array To Trigger An Overall Visual-Sensory Motor Integration In A Subject. Patent No. US 7,309,315 B2. 18 December 2007. United States Patent and Trademark Office.

5. Lacey, J.I., Lacey B.C. (1974). On heart rate responses and behavior: a reply to Elliott. Journal of Personality and Social Psychology, 30(1):1-18.

6. Liddle, E., Jackson, G., Jackson, SR. 2005. An evaluation of a visual biofeedback intervention in dyslexic adults. Dyslexia 11:61-77.

7. Bondorowicz, S., Kullok, S., and Kullok, J.R. (2004). A combination of computerized photic stimuli technology and special needs teaching: A new and efficient method to ameliorate deficits associated with dyslexia. Proceedings Sixth BDA International Conference, 27-30 March 2004, University of Warwick, UK

8. Bondorowicz, S., White Paper: A BrightStar Comparison study: Improvements in Dyslexic Children. Epoch Innovations. UK. 14 June 2003 .

9. Savage, S.L. Analysis of BrightStar Data. Internal document, draft. 9 June 2004. Epoch Innovations.

10. PricewaterhouseCoopers (2004). Epoch Innovations Attest Opinion Final.

11. Shaywitz, S.E. (1998). Current concepts: Dyslexia. New England Journal of Medicine, 338, 307-312.

12. Snowling, M.J. (2000). Dyslexia. Oxford: Blackwell Publishers Inc.

13. Talcott, J.B., Witton, C., Hebb, G.S., Stoodley, C.J., Westwood, E.A., France, S.J., Hansen, P.C., Stein, J.F. (2002). On the relationship between dynamic visual and auditory processing and literacy skills; results from a large primary school study. Dyslexia, 8, 204-225.

14. Lyon, G.R., Shaywitz, S.E., Shaywitz, B.A. (2003). A definition of dyslexia. Annals of Dyslexia, 53, 1-14.

15. Morris, R.D., Studebing, K.K., Fletcher, J.M., Shaywitz, S.E., Lyon, G.R., Shankweiler, D.P., Katz, L. Francis, D.J., Shaywitz, B.A. (1998). Subtypes of reading disability: Variability around aphonological core. Journal of Educational Psychology, 90, 347-373

16. Talcott, J.B., Hansen, P.C., Willis-Owen, C., McKinnell, I.W., Richardson, A.J., Stein, J.F. (1998). Visual magnocellular impairment in adult developmental dyslexics. Neuro-Ophthalmology, 20, 187-201 .

17. Fawcett, A.J., Nicolson, R.I. (2004). Dyslexia: The role of the cerebellum. In Reid, G. (eds) Dyslexia in Context. London: Whurr, pp. 25-47.

18. Stein, J., Walsh, V. (1997). To see but not to read; the magnocellular theory of dyslexia. Trends in Neuroscience, 20, 147-152.

19. Lovegrove, W.J., Martin, F., Blackwood, M., Badcock, D. (1980). Specific reading difficulty: Differences in contrast sensitivity as a function of spatial frequency. Science, 210, 439-440.

20. Stein, J. (2001). The magnocellular theory of developmental dyslexia. Dyslexia, 7, 12-36.

21. Stein, J. Talcott, J. (1999). Impaired neuronal timing in developmental dyslexia – The magnocellular hypothesis. Dyslexia, 5, 59-77.

22. Fawcett, A.J. Nicolson, R.I. (2001). Dyslexia: The role of the cerebellum. In A.J. Fawcett (ed.) Dyslexia: Theory and Good Practice. London: Whurr, pp. 89-105.

23. Nicolson, R.I., Fawcett, A.J., Berry, E.L., Jenkins, I.H., Dean, P., Brooks, D.J. (1999). Association of abnormal cerebellar activation with motor learning difficulties in dyslexic adults. Lancet, 353, 1662-1667.

24. Snowling M., Hume, C. (1994). The development of phonological skills. Philosophical Transactions of the Royal Society of London Series B-Biological Sciences, 346, 21-27.