LEARNING PROBLEMS:
Theoretical and Practical Considerations of Information Processing

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Abstract

Some 15 to 23 million people in the United States are diagnosed as having Attention Deficit Hyperactivity Disorder. Over a half-century ago, Dr. A.M. Skeffington described the essential elements of the vision process that have great relevance to the topic of learning problems. In the early 1990s, researchers demonstrated that vision and learning problems are related to information processing. This research indicated that some children with learning problems process visual information primarily with their magnocellular (magno) system. However, this paper proposes that there is a functional deficit of the magno system of these children. Thus, they are not able to effectively process the visual information that is available to them from this system. It is further proposed that accommodation can be utilized to link the magno and parvocellular (parvo) systems in the interest of optimal visual information processing. Current theoretical and practical considerations of information processing are discussed to better understand and ameliorate learning problems. It is recommended that the optometrist's role with these children is to improve magno system function, and then develop optimal interaction between the parvo and magno systems. Specific optometric techniques of diagnosis and treatment, with emphasis on accommodation, are described for children with learning problems in the interest of optimizing the interactions of the magno and parvo systems. Finally, a brief case history is presented detailing the practical application of parallel processing the parvo and magno systems.

Key Words

ADHD, Ritalin, learning problems, vision training, biofeedback, information processing, accommodation, magnocellular visual system, parvocellular visual system

Approximately 15 million children,[1] and approximately 8 million adults[2] in the United States have been diagnosed as having Attention Deficit Disorder/Attention Deficit Hyperactivity Disorder (ADHD) with accompanying learning problems. As is well described in the literature, 85% of those diagnosed with ADHD are prescribed Ritalin.[3] However, optometrists who treat vision problems on a behavioral/functional basis, raise the possibility that these learning problems can be caused or exacerbated by visual dysfunctions. The basis for this hypothesis was described more than a half-century ago by A. M. Skeffington, O.D., who from 1928 to 1976 was the Director of Education of the Optometric Extension Program (OEP).[4]

Among the many concepts introduced by Dr. Skeffington were:[4] (a) vision is a mode of information processing with a feedback loop; (b) sensory and motor integration is the basis and foundation for learning; and , (c) the importance of central-peripheral visual sub-systems in efficient visual processing. Taken together, these concepts strongly infer that children who have problems processing visual information will not be efficient learners. In fact, it has been my clinical experience that the majority of the children who have been labeled ADHD have an undiagnosed vision problem. The vision problem(s) manifests itself in either a focusing (identification) and/or a binocular vision (centering) deficiency.

These concepts have been stated to reinforce the fact that optometry, in general, and the work of Dr. Skeffington and OEP, specifically, have developed an approach to help remediate individuals with learning problems. It will be helpful to keep these introductory comments in mind while reading the present article.

Presently, only the most important clinical elements will be described. For a more detailed explanation of the critical importance of vision and learning see the work by Kaseno.[5]

Vision and learning

The model of vision proposed by Livingstone and Hubel[6,7] includes a dichotomy of the parvocellular (parvo) and magnocellular (magno) sub-systems. This dichotomy is present on structural and functional levels at all locations of the visual pathway from the retina to the visual cortex: there is a segregation of the parvo and magno cells.

Basically, the parvo cells exclusively occupy the central visual field, with the remainder of the visual field containing mixed parvo and magno cells. An appreciation of this dichotomy helps to more fully understand basic myopia and hyperopia and the part vision plays in learning. Basic to this understanding is that in order for efficient visual processing to take place, there must be an effective interaction between the parvo and magno systems. Table 1 contrasts the characteristics of these systems.[9]

Previous research has demonstrated that during accommodative relaxation, there is an attenuation of the theta brain wave, amplification of the alpha brain wave, and general muscular relaxation as measured by electromyography.[8] These changes are accompanied by the ability to

process many sensory channels simultaneously or, with regard to vision, to optimize the use of both the parvo and magno systems. Thus, accommodation can be the link to foster effective interaction between these two systems in the interest of optimal information processing, which is crucial to reading and learning.

Determining the type of processing/ attentional style of the patient

It is proposed that when evaluating an individual with a learning problem, the optometrist should determine the patient's characteristic processing style. The most accurate method is to have the patient read during an electroencephalographic recording: the beta wave has been related to central processing, the theta wave to peripheral processing, and the alpha wave to parallel processing.[10] However, this is not usually feasible in most offices. Consequently, careful observation of the patient can be a reasonable substitute. In the types of processing/attention listed below, parallel processing is the optimal state for effective reading and learning, while peripheral processing is the least effective mode, and is most characteristic of the child with learning and behavioral problems.

Models of processing/attention

1. ***Parallel Processing*** (PP) exists when both central and peripheral vision are processing information simultaneously. A speed reader is an example. He can see the exacting details of each word/letter (CENTRAL) and at the same time be aware of other words/letters on the page (PERIPHERAL). This state of attention also interacts synergistically with memory and other brain functions. Highly effective academic performers can sustain this type of attention appropriately.
2. ***Alternating Processing*** occurs when the central and peripheral information are processed one at a time; some can perform the alternation very quickly. The average college student will maintain this type of attention and may occasionally utilize PP but is not able to maintain this latter type of processing/attention on a consistent basis.
3. ***Central Processing*** exists when only detailed information is being processed in a serial fashion for a prolonged time. This processing is typical in many myopic individuals.
4. ***Peripheral Processing*** occurs when only peripheral information is being processed in a serial fashion. Consequently, the individual is "unfocused" and easily distracted by random thoughts or sensory stimuli not pertinent to the task at hand. This is typical in many individuals who are moderately hyperopic. They are the "C" students who have difficulty staying on the task because their creative-emotional processing is dominant. See Table 1. However, there appears to be another type of peripheral processor. With this type of individual the problem is that there is faulty functioning of this processing channel: the magno channel is not processing the information properly. It is proposed that this is the child with a hard core learning problem. Research has clearly demonstrated that some students diagnosed as having a learning problem have a malfunction of the peripheral (magno) system.[11] Thus, there are two types of Peripheral Processors: the "typical" hyperope, who is primarily a peripheral processor with a well functioning magno system, and the person with a "learning problem," who is primarily a peripheral processor with a faulty magno system. Usually, this patient has low hyperopia.

TABLE 1
PARVO VS MAGNO SYSTEMS

PARVO	MAGNO
Small Cells	Large Cells
Sustained	Transient
Bright Light	Dim Light
Low Contrast Sensitivity	High Contrast Sensitivity
High Spatial Frequency	Low Spatial Frequency
Center	Periphery
Identification	Centering
Analytical	Visceral
Left Brain	Right Brain
Cortical	Mid-Brain
Cognitive	Non-Cognitive
Logical	Emotional
Myopia	Hyperopia
Derivative	Creative
Stereopsis	Gross Depth Perception
Color Vision	Achromotopsia
Beta Wave	Theta Wave
Acuity	Motion
Small Receptive Field	Large Receptive Field
Focal	Ambient

Clinical observations

Because it is proposed that the accommodative mechanism is the link to optimize parallel processing, it is necessary to investigate it thoroughly. The following tests and considerations should be incorporated into the usual clinical routine

A. Latent hyperopia

It has been noted historically that hyperopia has been correlated with low academic achievement and poor reading ability.[12-16] Possibly, latent hyperopia is the most significant vision problem for learning-disabled children. This is particularly cogent in the second type of peripheral processor, as previously discussed, who manifests low hyperopia under usual testing conditions. Additionally, because of the frequent presence of an accommodative spasm in latent hyperopia, coupled with the manifest hyperopia itself, there can be an additional stress on these individuals' visual systems. Consequently, either a cycloplegic or delayed subjective refraction[a] should be performed to uncover any latent hyperopia. Another technique that can be used has been described by Miele.[17] He describes a subjective refractive procedure that utilizes an ascending and descending method of limits. Plus lens blur is reduced until 20/20 is read, then minus lens blur is reduced until 20/20 is read. The span between the plus and minus end points is known as the range of clarity.

B. Accommodative Function

Whether one uses the Accommotrac® Vision Trainer or flipper lenses, the dynamic functioning of accommodation (i.e., beyond the amplitudes) can be determined. These are the sustainability (i.e., length of time to fatigue) and the equality of each eye in all accommodative functions. It is noted that most children who have trouble learning are deficient in either one or both of these categories.

Using the Accommotrac® Vision Trainer, as accommodation reduces, the biofeedback sound increases in frequency. Accordingly, fatigue will be noticed by a decrease in the frequency of the

auditory biofeedback after a short time, 10 seconds or less of training. A difference in accommodative function between the two eyes can be noted by a difference in the frequency range in training each eye. Using flippers, the patient's performance can be compared to normative values.[18]

As a sympathomimetic drug, Ritalin increases hyperopia and reduces the amplitude of accommodation, thereby exacerbating any frailty of the accommodative system. Appropriate accommodative training is needed for these patients as well as additional techniques discussed.

C. Photophobia

Very often photophobia, a spasm of the iris,[19] is associated with accommodative spasm. As is well known, there is a common root for the iris and the ciliary muscles - if there is spasm in one, there tends to be a spasm in the other. During the slit lamp examination of the iris with low light, observe whether there is any hippus. This clinical observation is relevant to complaints of photophobia accompanied by eyestrain and ocular fatigue. Typically, a spasm of the iris would be thought to lead to pupillary constriction. However, in the case of the low hyperope with hippus, this is not the usual finding. While it might be expected to note a smaller iris due to spasm, an analogy can be made to spastic colon. In the latter case, there is an increase in the frequency and degree of contraction; however, the overall size of the lumen remains the same or mildly reduced.

D. Diplopia

A complete discussion of the dynamics between accommodation and convergence in regard to learning would require a separate paper, and is only mentioned here to stress its importance. Obviously, diplopia has very negative effects on learning and must be corrected.[20,21]

Diplopia has been noted to be a common problem for children who have been misdiagnosed as having a "learning problem." Quite frequently, the degenerating visual pattern of increasing myopia is associated with an increasing exophoria-exotropia or a deteriorating B syndrome. Concomitant with this increasing exo is diplopia - often unnoticed as it has developed insidiously. Accordingly, children who have had diplopia since an early age may be unaware that diplopia is not the norm. Particular attention should be given to this topic during the case history component of the vision analysis. While the thrust of the present paper is the relationship of accommodation to PP, certainly any successful treatment program must consider the patient's binocular vision pattern. While this may be obvious to some, many practitioners may not pursue the questioning of the child regarding diplopia. A helpful suggestion is to demonstrate diplopia with a trial lens prism. And then inquire again about experiencing diplopia. It is not unusual for children to think that diplopia is a normal concomitant of staring.

How to train PP

Translid Binocular Interaction Trainer (TBI)

Introduced by Merrill Allen 1967,[22] the TBI flashes light to both eyes, with the lids closed, at a rate of 9 Hz. The instrument was originally designed to reduce suppression. This frequency, 9 Hz, is in the Alpha brain wave band. In other words, the TBI puts people into a dominant Alpha brain wave mode that is photically driven. As discussed above, and will be discussed below, the Alpha wave is associated with utilization of PP and may help explain the beneficial effects reported after treatment with the TBI. The lasting effects of photically driven Alpha have not been reported, and most likely will vary from patient to patient. Accordingly, empirical evaluation of each individual patient will be required.

Biofeedback

The most effective way to enhance PP of visual information is by using biofeedback techniques, as will be discussed later. The key to the training is accessing the information pathways via the accommodative system. As the patient relaxes accommodation, he will have an expansion of his peripheral visual field. Once this can be accomplished on a consistent basis, central stimuli are introduced. Then, in order to perform the required task, he must not relax accommodation fully but must learn to optimize the accommodative relaxation to obtain the largest possible visual field and still maintain clarity of a central visual stimulus. The optimal accommodative relaxation may be related to the reported beneficial effects of low plus lenses by Pierce.[23] After the patient has mastered the balancing of central (parvo) and peripheral (magno) visual information, the distance at which the central stimulus is presented is changed. Finally, accommodative rock is trained while maintaining a wide periphery.

Other physiological measurements have been made while teaching patients these tasks, including electroencephalography (EEG) and electromyography (EMG). When the optimal amount of accommodative relaxation (sympathetic nervous system stimulation) is achieved, the patient goes into a dominant Alpha brain wave state. This is accompanied by a relaxation of the tension in the skeletal muscles. Other research has also shown the relationship between improved learning ability and a dominant Alpha EEG.[24,25]

Other considerations

Diet

There is evidence that children with learning disabilities are particularly sensitive to sugar.[26] Further, because of the appetite suppressing effects of Ritalin, these children eat little or nothing during the day, and maintain their activity by bursts of sugar binges. This causes their blood sugar level to vary with the concomitant swings in mood, etc. Chromium[27] is known to help in stabilizing the blood sugar level. The rest involves a sensible, balanced diet.

As both accommodation and blood sugar are controlled by the hypothalamus,[8] a disturbance in one function can have a deleterious effect on the other. Interestingly, Ritalin has another adverse effect in this regard. It has been reported to decrease the amplitude of accommodation and increase hyperopia due to its sympathomimetic property.[28]

Thus, the optometrist should request the child and/or parent to make a list of all the foods the child likes to eat and make a low sugar menu from the list.

Case history

As recently reported,[25] a combination of biofeedback techniques are used to train parallel processing whether the patient is a jet fighter pilot, professional athlete, or a child with a learning problem. The physiological functions that are trained are accommodation, EMG, and EEG. A 10-week protocol is utilized, which in most cases is highly effective in producing parallel processing with much

improved vision function. A case report of such training follows.

The patient was a 17-year-old male with a history of being a slow reader, and not being able to read for more than 10 minutes at a time. He reported that during reading the center fades and the words jump. Vision analysis revealed a small exophoria at near, 7-9 p.d., and manifest subjective refraction of O.D. -1.00 and O.S. -0.75 for 20/20. Ocular health, eye movement status, and visual fields were all within normal limits.

EEG analysis showed that after approximately 20 minutes of reading, the left and right brain recordings of both the Theta and Alpha waves became asynchronous, with the Theta waves becoming larger. (see Figures 1 and 2.)

In other words, there was a clear correlation between loss of reading comprehension and a dramatic change in the EEG. In addition to accommodative and EMG biofeedback training, he received training to increase the Alpha brain wave activity during reading. EMG training consisted of teaching the patient how to relax the frontalis and masseter muscles. General muscular relaxation is related to having an enhanced Alpha brain wave. His baseline of being able to maintain Alpha during reading was 1% of the time, and after 14 training sessions achieved 100%. Five years later, his mother sent the following letter:[29]

"Regarding the visual training program of Dr. Trachtman, I attribute his training as a significant contributor toward the success of my son, _____'s, academic performance. _____ graduated from College with a dual major of Biology and Chemistry. Following the results of his Biology GRE examination, he was accepted at the universities of _____, _____, _____ _____ and _____ in Bio-Medical research. In addition, all of these institutions offered _____ full free tuition as well as $15,500 a year. _____ chose the University of _____ and is doing quite well."

"As a Community Psychologist, working in a variety of settings and with diverse populations, I recognize a plethora of benefits that could be realized through the visual training program offered by Dr. Trachtman"

Improvement in accommodative function, EEG pattern, and EMG levels were accomplished as a result of the training program. This was reflected in his performance as he was transformed from a non-reader to a highly successful graduate student.

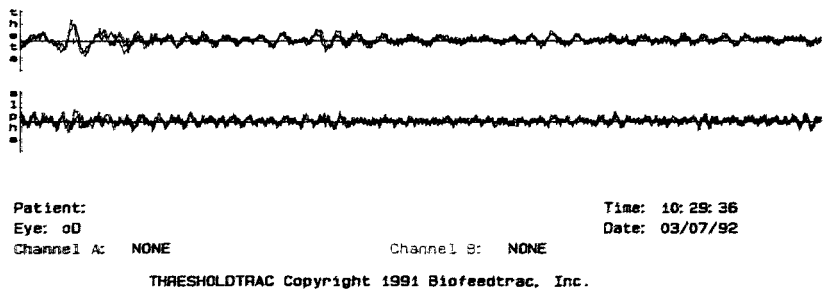

Figure 1. Electroencephalogram Recording At Beginning Of Reading,. Theta and Alpha waves were recorded from both cerebral hemispheres, with electrode placement at O1 and O2. In Figure 1, the Theta and Alpha waves are synchronized between the right and left, red and blue respectively, hemispheres, with equal amplitude between the Theta and Alpha waves. Each horizontal tic mark represents one second or the entire figure is 15 seconds. For the vertical scale: = is 1 microvolt. The AVT and EMG scales were not being simultaneously recorded during the session, and, therefore their values are constant at zero. For both Figures, in the Eye item, oD indicates the beginning of reading and oS the end of training.

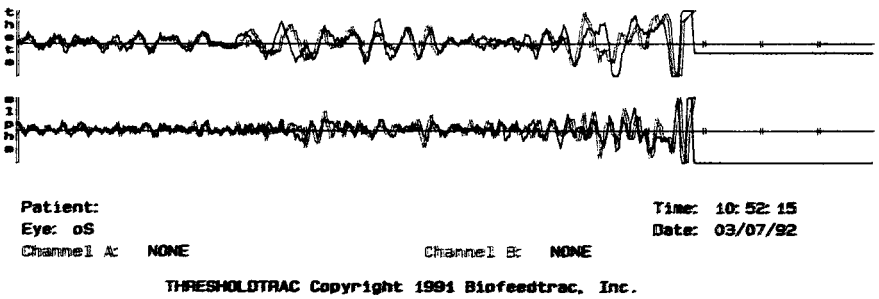

Figure 2. Electroencephalogram Recording at End of Reading. Theta and Alpha waves were recorded from both cerebral hemispheres, with electrode placement at O1 and O2. In Figure 2, the Theta and Alpha waves are not synchronized between the right and left, red and blue respectively, hemispheres, with unequal amplitude between the Theta and Alpha waves - Theta being larger. Each horizontal tic mark represents one second or the entire figure is 15 seconds. For the vertical scale: = is 1 microvolt. The AVT and EMG scales were not being simultaneously recorded during the session, and, therefore their values are constant at zero.

Conclusion

Theoretical and practical consideration have been presented relating the role of accommodation in information processing. More specifically, it is noted that many children who have learning problems have difficulty with their magno system function. The diagnosis of faulty accommodation accompanied by low hyperopia are strong clues that there is an imbalance between the parvo and magno systems. The practical applications of these theoretical considerations are demonstrated in a case history, where biofeedback was employed to increase accommodation function and the Alpha component of the EEG, leading to a marked improvement in information processing.

Many of the topics in this paper were noted by Dr. Skeffington over a half-century ago. As behavioral optometrists we have had, and still have, the unique opportunity and responsibility to be able to help millions of people labeled ADHD, who have been misdiagnosed, misunderstood, and subjected to frequently unnecessary powerful drugs.

Footnote

a."a. The simplest technique for disclosing the extra plus which the patient *will accept for steady wear* is the technique described by the author (1945) and also Baxter (1946), which consists of a simple combination of fogging and cyclodamia. b. At the conclusion of the phorometry routine, the last test usually taken at near is the test of negative relative accommodation during which plus is added until nearpoint letters are blurred. c. Leaving these lenses before the eyes, the nearpoint chart is removed and the patient's at-

tention is directed to the best line of letters seen during the subjective test, which are now badly blurred. d. The plus lens before the eye is reduced until these letters are again visible. (It is best to check this visibility point by the duochrome or other check methods used in determining the sphere during the subjective to be assured of the same degree of acuity.) e. Frequently, it will be found that the residue of this test exceeds the plus value found during the previous routine subjective." Borish, I.M. (ed.) Clinical Refraction. Third Edition, New York: Professional Press, 1970, pp 788-789

References

1. Wolraich ML, Lindgren S, Stromquist A, Milich R, Davis C, Watson D. Stimulant medication use by primary care physicians in the treatment of Attention Deficit Hyperactivity Disorder. Ped 1990:86(1):95-101.
2. Morrow DJ. Attention disorder is found in growing number of adults. The New York Times, September 2, 1997, A1,D4.
3. Wolraich ML, Hannah JN, Pinnock TY, Baumgartel A, Brown J. Comparison of diagnostic criteria for attention-deficit hyperactivity disorder in a county-wide sample. J Am Acad Child Adolesc Psychiatry, 1996:35(3):319-24.
4. Skeffington AM Introduction to clinical optometry. Santa Ana, CA:Optom Extension Prog, 1964.
5. Kaseno SL. The visual anatomy of the juvenile delinquent. Acad Therapy. 1985:21(1):99-105.
6. Livingstone MS, Hubel DH. Psychophysical evidence for separate channels for the perception of form, color, movement, and depth. J Neurosci 1987:7(11):3415-3468.
7. Livingstone M, Hubel D. Segregation of form, color, movement, and depth: anatomy, physiology, and perception. Sci 1988:240:740-749.
8. Trachtman JN. The etiology of vision disorders: A neuroscience approach. Santa Ana, CA: Optometric Extension Program, 1992.
9. Trachtman JN. What the athlete's eye tells the athlete's brain. presented at the International Academy of Sports Vision, June 9, 1990, Orlando, Florida.
10. Trachtman JN, Venezia CM. Central information processing and beta brain waves. Proceedings of the 1994 Association for Applied Psychophysiology and Biofeedback, Wheat Ridge, Colorado: 172-175.
11. Galaburda A, Livingstone, M. Evidence for a magnocellular defect in developmental dyslexia. Ann NY Acad Sci 1993:682:70-82.
12. Robinson HM. Visual efficiency and reading status in the elementary school. In: Clinical studies in reading III, Robinson and Smith (eds.), Supplementary Educational Monograph 97, Chicago: University of Chicago Press, 1968:48-61.
13. Hirsch MJ The relationship between refractive state of the eye and intelligence scores. Am J Optom 1959; 36(1):12-21.
14. Manly JN, Schuldt WJ The refractive state of the eye and mental retardation. Am J Optom 1970; 47(3):236-241.
15. Grosvenor T. Refractive state, intelligence test scores and academic ability. Am J Optom 1970; 47(5):355-361.
16. Young FA et al. Refractive errors, reading performance and school achievement among Eskimo children. Am J Optom 1970; 47(5): 384-389
17. Miele J. The range of clarity. J Optom Vis Dev 1986;17:24-27.
18. Siderov J, Johnston AW. The importance of the test parameters in the clinical assessment of accommodative facility. Optom Vis Sci 1990; 67(7):551-557.
19. King V. Discomfort glare from flashing sources. J Am Optom 1972;43(1):53-56.
20. Robinson HM. Why pupils fail in reading? Chicago: University of Chicago Press, 1946.
21. Eames TH. Visual problems of poor readers. in Clinical studies in reading II, HM Robinson (ed.), Supplementary Educational Monograph Number 77, Chicago: University of Chicago Press, 1953.
22. Allen MJ Shock treatment for visual rehabilitation. Opt J Rev Optom 1969;108(24):27-29.
23. Pierce JR. A study of the relation between performance and physiological activity as a function of nearpoint lenses, working distance and posture. Doctoral Dissertation, University of Portland, May, 1970.
24. Ludlam WM. Visual training, the alpha activation cycle and reading. J Am Optom Assoc 1979;50(1):111-115.
25. Trachtman JN. Finding the zone: case studies of parallel processing and electroencephalogram. Int J Sports Vis 1997;4(1):6-11.
26. Girardi NL, Shaywitz SE, Shaywitz BA, Marchione K et al. Blunted catecholamine reponses after glucose ingestion in children with attention deficit disorder. Pediatr Res 1995;38(4):539-42.
27. Kitchalong L, Fernandez JM, Bunting LD, Southern LL, Bidner TD. Influence of chromium tripicolinate on glucose metabolism and nutrient partitioning in growing lambs. J Anim Sci 1995;73(9):2694-2705.
28. Trachtman JN The efficiacy of the use of Ritalin for hyperactive children – A critical evaluation. J Behav Optom 1991; 2(7):179-185.
29. Personal communication, December 10, 1997.

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