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VISUAL PERCEPTUAL FACTORS AND READING:

CLINICAL IMPLICATIONS OF SOME RECENT OPTOMETRIC RESEARCH

ABSTRACT

This article provides the reader with the opportunity to follow the development of visual perceptual skills in normally achieving children from kindergarten through grade five. The research was previously published in a series of individual articles, but lacked the continuity provided in the present review. Of special interest to the optometrist is the strength of the relationships of visual perceptual skills with reading comprehension and arithmetic in the elementary grades. Concurrent and predictive validity are also addressed. In addition, the article provides evidence that, as task demands change during this period, visual processing modes accommodate to the normally achieving child's needs. This is not so, however, with reading-disabled children. Implications for diagnostic and therapeutic regimens are discussed.

KEY WORDS

Reading disability, perceptual testing, simultaneous processing, successive processing, Grooved Pegboard Test, Divided Form-Board Test, Auditory-Visual Integration Test, Tachistoscopic Exposure Test

Clinical impressions and professional intuition play a significant role in the optometric treatment of patients who have been identified as reading- and/or learning-disabled. However, clinical impressions are not infallible. The purpose of this article, therefore, is to share with the clinician the results and implications of some of the research which has been completed in the Learning Disabilities Unit, State College of Optometry/SUNY. Specifically, the visual perceptual development of normally achieving children will be traced longitudinally from kindergarten through grade five. Also addressed are the particular problems of reading-disabled children in grades four-six. It is of special interest to note that this research supports diagnostic and therapeutic procedures in current optometric practice.

A number of major strategic decisions had to be made initially. First, we decided to study normally achieving children prior to children with reading and learning disabilities. This enabled us to develop normative baseline data. For the purpose of this study, normally achieving children were defined as a population sample having the following characteristics: WISC-R intelligence within the normal range (IQ > 90), at least average educational opportunities, and normal sensory acuities for hearing and vision. These children had no frank brain damage nor was any child experiencing a primary emotional problem. And, finally, only a small percentage of the children were socially and economically disadvantaged. The distribution of the normative data, therefore, was not confounded by health, nutritional, and emotional disorders.

KINDERGARTEN STUDY

We further decided that our initial population should be kindergarten children. This plan enabled us to conduct a longitudinal study of normally achieving elementary school children. Our primary research question was: "What are the relationships between visual perceptual skills and learning in kindergarten, and how do they change as the child proceeds in elementary school?" The kindergarten test battery[1] that evolved was the product of a number of a developmental rationales as well as prior research.[2-8]

Tests Chosen

After establishing the nature and grade level of the population sample, we identified the specific tasks (the independent variables) to be evaluated. Prior investigators, optometrists and others,[6,9-11] had indicated that the efficiency with which an individual processes visual stimuli is clinically important in distinguishing good from poor readers.

Therefore, we selected the Tachistoscopic Exposure Test (Appendix A) using two digits at .1 and .01 seconds. This test subsumes the cluster of visual processing skills normally associated with good reading and learning: i.e., visual memory, rehearsal prior to storing the stimulus, encoding, accuracy and automaticity, and perceptual speed. The Six Figure Divided Form-Board Test (Appendix A) provides the observant optometrist with the opportunity to probe the maturity of the child's perceptual-motor functioning along several other dimensions: In addition to basic form perception and spatial skills, he can make a judgment regarding the child's cognitive style in terms of impulsive or reflective behavior. That is, does the child delay his motor response long enough to conceptualize the visual gestalt of the various geometric forms, or is the child impulsive?[12] Another clinical observation is whether a tactile strategy is still being applied at the end of kindergarten. If it is, there may be a delay in the normal ontogenetic development of visual dominance. A child entering grade one is ready to read when the teleoreceptor systems, especially the visual, are dominant over the proximal receptor systems, such as tactile. A child is *not* ready to read when concurrent tactile stimulation does not act as essential background to the visual percept, but rather as a displacement stimulus which can cause disorganization of the visual percept.[3]. The Grooved Pegboard Test (Appendix A) is a more complex sensory-motor integration task. It measures the child's ability to integrate visual, tactile and kinesthetic stimuli with fine motor skills. When performing this task, the tactile-visual feedback enables the child to feel when the peg is correctly aligned with the direction of the keyed slot. Visual feedback is required, however, to accurately center the peg over the hole in order to complete the task. Automaticity is measured by timing the performance in each of the tasks.

Investigations by Birch and Belmont[4,13] supported the hypothesis that learning to read requires the ability to equate a *temporally* distributed *auditory* stimulus (taps) to a *spatially* distributed *visual* array (configuration of dots). Subsequently, other investigators have refined the procedures necessary to perform an auditory-visual integration task. For example, Goodenow[14] controlled for auditory memory by having the subjects repeat the auditory stimulus. If the child can not repeat the *taps*, it is unlikely that he will be able to select the correct visual response. Blank, Weider, and Bridger[15] observed that temporal-spatial integration may involve an intermediate step to permit the child to verbally encode the sequence of the *taps*. Solan et al.[18] demonstrated that *both* intersensory *and* temporal-spatial integrations within the visual modality are significantly related to reading achievement in grade one. The intramodal temporal-spatial task was accomplished by replacing the auditory taps with a flashing light. It was determined that 58% of the variations in auditory-visual integration could be accounted for by variations in the intramodal temporal-spatial integration alone. Consequently, the final test utilized in the battery was the Birch-Belmont Auditory-Visual Integration Test. (See Appendix A.)

Relating Test Scores to School Performance

Since one of the goals was to provide preliminary clinical norms, the procedures were carefully standardized and reported in the study.[1] Bivariate correlations (r) were calculated between the total score of the Readiness Level of the SRA Primary Mental Abilities Tests[16] and the scores on each of the independent variables: The Tachistoscopic Exposure Test (TET); the Grooved Pegboard Test (GPBT), the Divided Form-Board Test (DFBT) and the Auditory-Visual Integration Test (AVIT). All of the bivariate correlations were statistically significant ($P<.01$) with the exception of the AVIT. It is possible that some of the kindergarten children had difficulty conceptualizing the AVIT, or successful performance on the readiness test did not require proficiency in this area. These correlations were important since they told us how the dependent variable, learning readiness, co-varied with each of the perceptual skills. For example, a correlation of $r = +.526$ between readiness and tachistoscopic performance suggests that a high score on the tachistoscope test would probably yield a high level of readiness. The higher the correlation (between 0 and 1), the stronger the relationship.

Using the data from those tests which showed significant bivariate correlations, a *multiple regression correlation*[a] with the total readiness score was calculated. The additive nature of the individual perceptual factors confirmed what astute clinicians have recognized for sometime: the strength of the linear association between visual perception and readiness is greater when the three factors are considered simultaneously than when each is considered individually as in bivariate correlations. The coefficient of multiple correlation (R) in the Kindergarten Study was calculated to be $R = +.737$ ($P<.0001$). This relationship strongly supports the hypothesis that a child of kindergarten age, whose scores on the TET, GPBT and DFBT are good, is likely to have a high readiness score. The use of these results for a valid optometric perceptual screening battery becomes quite apparent.

Concurrent Validity

The coefficient of correlation, R, defines the relationship between the dependent and the independent variables. The correlation square (r^2), called *percent of variance*,[b] is a measure of the commonality of function between the dependent variable, learning readiness, and the independent variables, TET, DFBT, and GPBT. In the Kindergarten Study, the corresponding R^2 for the multiple correlation is .543 or 54%. This tells us that the combined effect of the variations in these visual perceptual tests account for 54% of the variations in learning readiness. Other variables, such as IQ and the ability to apply the appropriate learning strategies when presented with a novel task, contribute to the remaining 46%. The study confirmed that these tests may be employed toward the determination of the existing status of a child's readiness to learn at the end of kindergarten.

GRADE ONE STUDY

The complete battery of perceptual tests was administered to the same population at the end of grade one.[12] When the bivariate correlations with the Vocabulary Subtest of the Gates-MacGinitie Reading Tests (Level A) were calculated, the results were similar, although there were two notable exceptions. The Grooved Pegboard Test showed a much weaker correlation than was found in kindergarten, and the correlation of the AVIT with reading vocabulary was strongly significant. As the correlation of the Grooved Pegboard Test with reading vocabulary was barely significant, the test was not included in the ensuing multiple correlation. The multiple regression correlation of AVIT, TET, and DFBT with the Reading Vocabulary Subtest was $R = +.716$ ($P<.0001$). The R^2 was .513 which corresponded to a common variance of 51%. Again, more than half of the variations in the dependent variable, vocabulary, could be accounted for by variations in these perceptual tests.

PREDICTIVE VALIDITY

At this juncture we investigated the relationship between perceptual tests measured at the end of kindergarten and reading skills at the end of grade one using multiple correlation statistics. Tests that showed the strongest bivariate correlations at the end of grade one were selected as the independent variables: the Tachistoscopic Exposure Test, the Divided Form-Board Test, and the Auditory-Visual Integration Test. The scores of these tests measured at the end of kindergarten correlated significantly with both vocabulary and reading comprehension at the end of grade one, $R = +.569$ ($P<.0005$) and $R = +.496$ ($P<.001$) respectively. That the AVIT, administered at the end of kindergarten was not significantly correlated to readiness, but was a significant factor at the end of grade one, illustrates the changing perceptual requirements of the primary grade child. Of further interest to the optometrist and the educator is that the combined effect of the three perceptual skills showed good predictive validity; their multiple correlations were statistically stronger than the SRA Primary Mental Abilities Test (Readiness Level) with both vocabulary and reading comprehension.[12]

GRADE TWO STUDY

At the end of grade two, the perceptual and the Gates-MacGinitie Reading Tests (Level B)[17] were administered to the same population of children. Contrary to expectations, a dramatic reduction in common variance took place when the children were tested at the end of grade two. The bivariate correlations between Vocabulary and the Tachistoscopic Exposure Test and the Auditory-Visual Integration Test remained strong, but the Grooved Pegboard replaced the Divided Form-Board Test in the stepwise multiple correlation. The common variance (R^2) of the perceptual tests with reading vocabulary was reduced to 25% ($R = +.499$; $P<.001$) and with comprehension to 22% ($R = +.473$; $P<.001$). The amount of variance *not* accounted for by the three perceptual skills, therefore, increased to 75% and 78% respectively at the end of grade two. How may this be explained? How do the perceptual and cognitive demands at the end of grade two differ from the end of grade one?

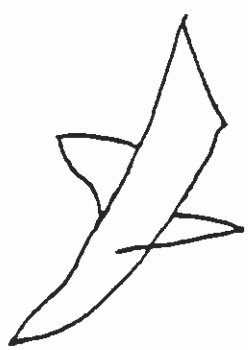

Figure 1. Example of a drawing of a vertical diamond using successive rather than simultaneous processing.

SUPRAMODAL PROCESSING

To answer these questions the concepts of spatial/simultaneous and verbal/successive processing must be explored, albeit briefly. In simultaneous processing, perceived stimuli are totally surveyable or globally available at one point in time; whereas in successive processing, information is presented consecutively in serial order as in speech. Comparison of the two systems of processing makes it possible for the optometrist to distinguish between two different types of readers: the reader with the ability to convert the consecutive presentation of elements of incoming information into a new quality of simultaneous perceptibility, and the one who may have a good understanding of the meaning of individual words but not grasp the meaning of the thought as a whole.[18] This same phenomenon reveals itself in an aspect of visual motor development. The child who copies the divided rectangle, the horizontal diamond and the vertical diamond one line at a time and produces the picture illustrated in Figure 1 is not using a global (simultaneous) strategy. Instead, successive strategy is being used since the child is processing consecutively, line by line.

The cognitive demands of kindergarten predominantly require spatial/simultaneous skills. First the child is asked to recognize, discriminate, analyze, synthesize, and perhaps reproduce whole pictures and/or figures. Since the stimuli are always "globally available," serial processing would be a poor strategic choice. It is not surprising that the child who is deemed ready to enter grade one shows good simultaneous skills as measured by the Divided Form-Board Test and the Tachistoscopic Exposure Test. Although, the Grooved Pegboard Test is primarily a successive task, it should be recognized, however, that the placing of the keyed pegs in the grooved slots assesses additional aspects of readiness such as directionality, ability to integrate subskills, and fine motor skills.

In grade one, learning whole words replaces copying forms and figures. To accommodate the increasing need to equate a temporally distributed auditory stimulus to a spatially distributed visual response for the child who is about to learn phonics, a measure of auditory-visual integration, the AVIT, consequently replaces the Grooved Pegboard Test. It is not until grade two, however, that a primary need for successive processing truly exists. Decoding by syllables and fluent oral reading are hallmarks of the achieving second grade reader. Indeed, at the end of grade two, spatial/simultaneous processing remains a necessary but not a sufficient condition for reading competence. Thus, the multiple correlation of vocabulary with the predominantly spatial perceptual tests used was diminished from R = +.716 (R^2=51%) in grade one to R = +.499 (R^2=25%) in grade two.

GRADES FOUR AND FIVE STUDIES

We had the opportunity to evaluate a new, but similar, population of normally achieving fourth and fifth grade students whose full scale intelligence was average or better.[19,20] Experience with the grade two children suggested that we test this normally achieving group initially with the Gates-MacGinitie Reading Tests (Level D)[17] and compare the results with both spatial/simultaneous and verbal/successive tasks. The simultaneous tests included the Developmental Test of Visual Motor Integration (VMI),[21] AVIT, Block Design,[22] Tachistoscope, and Spatial Relations,[16] while the successive tests were drawn from the verbal subtests of the WISC- R[22] which had been administered previously. The results supported the earlier findings of Das, Kirby, and Jarman.[23] We found that *proficiency in both, successive and simultaneous processing, is necessary for good reading skills. Neither by itself is sufficient for high achievement.* In this research, the percents of variance of the vocabulary subtest with the verbal and spatial tasks were similar, 39% and 41% respectively. Comprehension was more highly correlated with verbal than spatial skills, although a t-test between coefficients of correlations did not reveal a statistically significant difference.

Using this same group of normally achieving fourth and fifth grade students, the multiple correlation of the visual spatial tests was significantly greater than the verbal tests with the written arithmetic subtest of the Wide Range Achievement Test (R = +.822, P<.001 compared to R = +.421, P<.01). That 68% (R^2) of the variations in written arithmetic may be accounted for by variations in spatial skills supports the potential for the optometric treatment of visual and perceptual dysfunctions in children who are experiencing problems in written arithmetic. Children with spatial dyscalculia have difficulties in organizing arithmetical responses on a page and confuse place values when creating arithmetical columns. Visual spatial defects hinder mathematically knowledgeable children from doing paper and pencil calculations correctly. It should be noted that in the performance of mental arithmetic, an orally administered test, verbal factors appeared to exert a greater, albeit not statistically significant, influence than spatial skills. These results do not imply that successive processing is not helpful in written arithmetic or that simultaneous processing, as in visualization, has no effect on performing mental arithmetic.

The findings are consistent with the research of Cummins and Das[24] who proposed that the role of simultaneous and successive processing may vary at different developmental levels. In particular, successive processing may be important for the mastery of early decoding (e.g., grade two). Other investigators have provided evidence that the processing systems may also be differentially important with respect to achievement level. Better readers tend to show higher levels of simultaneous processing than poorer readers.[22]

READING-DISABLED CHILDREN

Using five simultaneous and six successive tasks, 51 reading-disabled (RD) children, whose mean WISC-R IQ was average but whose mean comprehension score on the Gates-MacGinitie Reading Test (Level D)[17] was at the 20th percentile, were compared with a population of normally achieving fourth-, fifth-, and sixth-grade children.[25] Unlike the normally achieving children who are proficient in both modes of processing, successive and simultaneous, four of the five tests which correlated with reading comprehension in the RD group were successive (King- Devick,[26] Grooved Pegboard, Digits Backward,[27] Token Test[28]). In the fifth, AVIT, the stimulus is successive, but the response is simultaneous. In a stepwise multiple regression procedure correlating these five independent variables with reading comprehension, the weight and number of factors strongly supported the predominant influence of successive processing on this group of RD children. The first three, which provided 38% of the variance, were visual perceptual integration tests (King-Devick, GPB, and AVIT). The remaining two verbal tests increased the variance by just 2% which is of no clinical importance. These findings lend support to the observations of other investigators[24] that, in elementary school, the two processing systems may also be differentially important with respect to achievement level. Whereas normally achieving students use both simultaneous and successive processing with equal facility, RD children in grades four-six depend upon successive processing to a greater degree, a factor which may, indeed, be related to their poor comprehension skills.

CONCLUSIONS

In this review, the visual perceptual development of normally achieving children is traced longitudinally as it relates to visual perceptual maturation and supramodal processing. As the task demands change, it is interesting to note how the processing modes, spatial/simultaneous and verbal/successive, accommodate to the normally achieving child's needs. Even when the importance of verbal/successive processing increases, visual perceptual organization and spatial skills remain necessary attributes. The processing systems are non-hierarchical; both simultaneous and successive processing skills are necessary for academic achievement.

The study involving disabled readers reinforces the potential for optometrists to identify, through the use of the appropriate diagnostic tests, those children who have specific visual processing deficits which affect their ability to perform effectively in reading and arithmetic. Proficiency in both modes of processing is necessary for good reading comprehension: successive to read the consecutive words in a sentence and simultaneous to enable the child to grasp the meaning of the thought as a whole. The observation that these RD children with normal intelligence were not using the appropriate spatial/simultaneous processing skills for comprehension is indeed remarkable. Since many optometric vision therapy programs are weighted in favor of the development of spatial skills, our findings appear to explain the reason for the increased reading comprehension and arithmetical skills coincident with the improvement in simultaneous processing skills. For each child, an individual therapy program must be designed that not only addresses the deficits revealed, but also includes techniques for the child to learn when to apply the correct processing strategy.

APPENDIX A: METHODS AND PROCEDURES [c]

Tachistoscope Exposure Test

Each child was given a paper with two identical columns. Letters a, b, and c at the top of each column were for familiarization trials and numbers one through 10 below were for the test exposures. The children were tested using a Tach-X tachistoscope located eight feet from the screen flashing two digits (kindergarten), three digits (first grade), four digits (second grade) or five digits (fourth and fifth grades). In order to minimize the amount of verbalization of the digit sequence, six children at a time were tested seated six feet from the screen.

First, the digits were exposed at 0.1 seconds for the practice trials so the children would know what to expect. They were instructed to record the digits as they remembered them after the flash. To alert the children before each exposure, the examiner said "Look at the screen. Ready, now." After each practice exposure the shutter was opened so the children could determine if they had recorded the proper digits. Following, there were 10 test exposures at 0.1 seconds, and the children recorded the digits next to the numbers one through 10 in the left hand column. The entire procedure was repeated at 0.01 seconds and the results were recorded in the right hand column.

Each digit which was recorded in proper sequence was scored one point. For example, in kindergarten, 26 recorded as 28 would receive one point, but 62 would receive 0 points. Two separate totals were computed for 0.1 seconds and 0.01 seconds.

Grooved Pegboard Test

Prior to administration of the Grooved Pegboard portion of the test battery, hand dominance was established using the following protocol: The children were told that they would play a game in which they would pretend to do things. They were instructed to "show me how you brush your teeth." The examiner noted which hand was used in the demonstration. This was followed by the child demonstrating how to "hammer a nail," "cut with scissors," "write with a pencil," and "throw a ball." The dominant hand was considered to be the hand which was involved in the majority of the demonstrations, usually five out of five.

The Grooved Pegboard (25 holes, 5 x 5 array) was placed on the table directly in front of each child who was then shown the keyed pegs and how they fit into the grooved holes. The child was told to pick up and place only one peg at a time and use only the one hand indicated by the examiner. (The dominant hand was tested first in order that any transfer of learning would minimize dominant versus non-dominant differences rather than exaggerate them.) The examiner then pointed from hole to hole and row to row in the order that the pegs were to be placed The pattern consisted of sequential left to right placement in rows one through five for the right hand, and right to left placement in rows one through five for the left hand.

The children were given three to five trial placements in order to familiarize themselves with the task. Then they were told that they were to place all of the pegs as fast as possible. Task execution time was considered to begin when the examiner said "Go" and to end when the last was successfully filled. After the dominant hand was completed the pegs were removed and the non-dominant hand was timed. The child was given no help during the time portion of the test, however occasional reminders of the peg placement order were provided if needed. This was accomplished with minimal interruption to the test.

Six Figure Divided Form-Board Test

The child was first given the opportunity to see the Six Figure Divided Form-Board assembled and observe the examiner disassembling the 12 pieces which were placed in random order around the board. A special effort was made to separate complementary pieces. No practice was provided, and the examiner offered no assistance to the child, although encouragement was always in order. The child was told: "Place the pieces back in the board as fast as you can. Use all the pieces. Start."

The child's performance was timed, although the timing was done inconspicuously in order to avoid inducing stress. The time to completely reassemble the board was recorded. If the child did not complete the task in three minutes (180 seconds), the test was discontinued and scored 180+ seconds.

Each child was carefully observed. While kindergarten children do not usually have the visual capabilities to combine the two halves of a figure prior to placing them in the inset, neither should they engage in trial and error—a completely tactile approach. The manner in which the child handles the piece is also significant, but not scored numerically. Does he use two fingers or does he wrap his hands around the form to provide haptic reinforcement for the visual input?

The test provides the astute observer with a measure of the child's problem-solving ability. The child's ability to recognize a gestalt is also evident. That is, does the child recognize spontaneously that the whole is the sum of the parts.

Auditory Visual Integration Test

The Auditory-Visual Integration Test (AVIT) involves an auditory-visual pattern matching task which was developed by Birch and Belmont. The auditory stimuli were generated by tapping a pencil on the edge of the examining table. During the procedure the examiner's hand with the pencil, as well as part of her arm, were concealed from the subject. The temporal distribution of the taps were one-half second pause between short intervals and a one second pause between long intervals. The visual spatial matches (printed dot patterns) were not available to the subject at the time of the presentation of the taps, but were presented on an individual 4 x 7 inch card from which the subject made his choice.

During the testing procedure the child and the examiner were seated at opposite sides of the examining table facing one another. The examiner said "I am going to tap out some patterns." The child was then shown the response card, containing the visual dot patterns and told: "Each pattern you hear is going to be like one of the dot patterns you see here." The examiner then pointed to the card and said, "Let me show you. These are two dots close together. Listen to what they sound like." The examiner tapped out the three patterns on card No. a. One of the patterns was then tapped out again and the child was asked, "Which one did you hear?" After the child responded, the examiner verified the correct response for the child.

For the next two examples, b and c, the examiner said, "Listen again, and then show me what you heard." After the presentation of the three practice examples, but prior to administering the 10 test items, the child was told: "Listen carefully and pick out the dots which look like the taps you hear. I will not show you the card until after you hear the taps." The child scored one point for each correct response on the AVIT. A perfect score was 10.

ENDNOTES

a. The two main principles of multiple correlations are: 1) A multiple correlation increases as the size of the bivariate correlations between dependent and independent variables increase; and 2) A multiple correlation increases as the strength of the intercorrelations of independent variables decreases.[29]

b. The statistic r^2 (R^2 in the case of multiple correlation) indicates the amount or percent of variance in one variable accounted for by its linear relationship to the other variable.

c. Appendix A is reprinted with permission from the Journal of the American Optometric Association: Solan HA, Mozlin R, and Rumpf DA. Selected perceptual norms and their relationship to reading in kindergarten and the primary grades. 56(6): 1985.

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Date accepted for publication:
12/21/1989