Evidence for Familial Link in Visual Processing Disorders

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Background: Visual information processing is the visual-cognitive ability to extract, organize, manipulate, integrate and process visual input. Visual processing disorders can have a significant effect on school performance. While many clinicians have observed a trend of visual processing disorders within the same family, there is little research in this area to suggest a relationship. The possible association between the heritability of visual processing disorders and hair color in this family was investigated.

Methods: A family consisting of two parents and eight qualifying children with suspected vision processing disorders was recruited. Subjects ranged from 5 years to 45 years of age at the time of testing. All were given a vision information processing assessment by an experienced examiner. The test battery consisted of 11 tests including: the Matching Familiar Figures Test, the Visual-Aural Digit Span, the Letter Sequences subtest of the Detroit Test for Learning Aptitude, the Visual Motor Speed and Precision Test, The Beery-Buktenica Visual-Motor Integration Test, the Developmental Eye Movement Test, the Jordan Left-Right Reversal Test, the Test of Word Reading Efficiency, the Dyslexia Determination Test, the Peabody Picture Vocabulary Test, and an evaluation for persistent primitive reflexes, specifically, the Moro and Asymmetric Tonic Neck Reflexes. Scores were recorded for all areas, and subjects were grouped by sex and light or dark hair color to attempt to draw associations for each test and for any overall relationships.

Results: All subjects except one demonstrated persistent primitive reflexes, indicating delayed gross motor development. All subjects scored within the age-expected ranges for the Peabody Picture Vocabulary Test, but results were varied across all other testing. In general, the dark-haired males had lower averages for visual information processing tests when compared to the light-haired individuals.

Conclusion: There appears to be significant associations between the scores of family members on visual processing tests, however, the role of environment cannot be ruled out as a factor. Dark-haired male children produced similarly poor vision information processing test results when compared to light-haired children, all but one being female. There is need for more research in the area of heritability of visual processing, especially as it relates to gender and hair color.

Keywords: persistent primitive reflexes, visual information processing, visual memory, visual motor integration, visual processing, vision therapy

Introduction

Visual information processing is the ability to extract, organize, manipulate, integrate and process visual information from the environment. The majority of research involving this area has occurred in the fields of neuroscience, psychology and education. Anatomical and physiological examination of neurologist stimulation while processing certain types of visual information is one such research category.

The visual cortex is an important structure in visual information processing and may influence processing in other portions of the brain.
The visual cortex is a key player, the hippocampus, fusiform gyrus (fusiform face area), parahippocampal gyrus (parahippocampal place area), amygdala, right inferior frontal gyrus, intraparietal sulcus (IPS), ventral lip of the collateral sulcus, frontal cortex and pre-frontal cortex are also involved in certain visual tasks. The portions of the brain and pathways stimulated are a result of diverse visual input and the demands of the task. For instance, visual memory appears to occur, at least in part, at the level of the cortico-hippocampus as a result of temporally-spaced episodes of synaptic reconfigurations. In addition, the mirror neuron system (MNS) has been suggested as an integrative link between the auditory, visual and motor pathways by using sensory information to direct movement.

The complexity of visual information processing and lack of accessible and cost-effective equipment to pinpoint the sites of neurological deficit lead to difficulty assessing the etiology of one or more specific visual processing problems. Increased use of functional Magnetic Resonance Imaging (fMRI) technology may make future research on this topic easier to obtain. There is much to learn in regards to visual processing pathways, leading to difficulty connecting a particular pathway to the results of one visual processing subtest. The clinician must utilize a battery of subtests, many of which provide overlapping data, to derive a more complete evaluation of the visual processing system. Such evaluations also allow categorization of functional strengths and weaknesses. Although the ocular structures capture visual information, it is the brain that processes, assigns meaning and integrates it with other sensory information through complex and integrated neural pathways.

The heritability of visual processing performance has been examined. Both inspection times indicating the speed of central visual processing and IQ, particularly performance IQ on the WISC-III, have proven moderate to high heritability. There have also been proven overlaps between heritable disorders and visual-perceptual deficits. Fragile X affected individuals have an expanded nucleotide sequence on the X chromosome that is suspected as being the etiology of the noted neuro-developmental deficits associated with this syndrome. These individuals demonstrate visuo-spatial and motion perception difficulties for instance. In addition, Pennington and Lefly found prevalence between 33% and 50% of a family-related dyslexia history.

The seemingly high rate of visual information processing disorders in siblings and parents of affected children versus the general population has been observed by practitioners clinically, begging the question as to whether a familial tendency can be documented in research. Is there evidence for the role of nature, nurture or both as a predictor for visual processing disorders? To explore this question, an intact nuclear family with ten children ranging in age from one to 22 years of age with married parents was recruited for this study.

An assessment of the entire family began with a comprehensive eye examination of two symptomatic children. The comprehensive examination including binocular vision and sensorimotor evaluation revealed a common trend of convergence insufficiency decompensating to intermittent alternating exotropia with fatigue in the six children examined, as well as a variable, small vertical heterophoria in two of the children.

Even though academic success and reading were valued by the parents, all school-aged family members exhibited severe academic difficulties based upon elicited case histories. Problems were especially severe for each child in pre-reading or reading skills and some additionally displayed fine and gross motor delays, inability to remember the names of letters after multiple exposures, poor handwriting, social awkwardness, lack of motivation to complete school work and tracking difficulties among others (see Table 1).

Throughout initial examinations and study testing, the children were always polite and respectful. They appeared well cared for and seemed to have their needs met at home. The parents were also pleasant and approached each child’s problems individually. The mother has homeschooled all of the children. Two of these children were younger than age 5 and not yet in school, six of primary school age, one age 20 and in college.

The decision to home-school was based largely upon a negative experience with the oldest two children who struggled in a private school environment and the parents’ feelings that the needs of the children were not being met. They stayed in the public school until ages 7 (2nd grade) and 11 (5th grade), respectively, and were then pulled and immediately immersed in homeschooling following the standards guidelines of the state of Michigan. Since that time, none of the children have attended school outside of the home.
Histories were significant for confirmed visual processing disorders in four of the children based on an assessment by a local developmental optometrist. Two of the children had optometric vision therapy discontinued before completion of the therapy program. The eldest child was diagnosed with an auditory processing disorder and had received minor accommodations through disability services at the university she attends. The mother stated she is quite certain that other children have auditory processing disorders and they have been referred for testing. The parents described a family tendency towards visual processing disorders and that the dark-haired boys appear to suffer from the largest deficits as they relate to academics and reading. They felt that the light-haired siblings also display similar academic/reading problems of a lesser severity. Of note, subjects 8 and 9 are dizygotic (fraternal) twins, one dark-haired male and one light-haired female.

The mother and father both stated a history of academic strengths and weaknesses. The mother, age 45, is an avid reader, especially for pleasure and is proud of her fluency and vocabulary. She stated that as a young child she was a good artist but became discouraged in her abilities as an older child and quit drawing altogether. She admitted poor handwriting ability and sometimes clumsy gross motor abilities, as well as occasionally poor memory that she attributes to her busy family life. Interestingly, she also explained an aversion to anything touching her face, especially glasses “which drive me crazy.” Although wearing flat-top bifocals, she stated that she had never gotten used to them.

The father, age 44, disliked school as a young boy and struggled to keep his attention on his studies. He stated that he is not a strong reader and believes he has a “learning disability” although it was never formally diagnosed. He has difficulty with reading words he has not encountered before, along with poor phonetic ability. In addition, he is frustrated with his poor memory, especially when listening and attempting to remember things in daily life, such as taking a message or phone number over the phone. He relies on leaving little notes for himself and writing everything down. His skill and interests lie in “figuring things out” mechanically or with motor manipulation. The father’s work involves driving delivery and physical labor but he is proud of his many additional “projects” in his workshop, including building an addition onto his home and other smaller building and mechanical projects.

In order to compare and contrast scores amongst family members in the area of visual information processing, each family member of testable age was given an identical battery of tests. The typical test battery used for the assessment of visual information processing varies from office to office. Particular tests were selected for this study based upon statistical validity of the normative data and test design, broad topic coverage and ease of administration. Although the Visual Information Processing Assessment (VIPA) is primarily addressing the ability to manipulate visual information, there are some subtests that may provide indication of auditory processing problems. If problems are detected in this area, the patient is referred for a complete auditory evaluation. In

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Table 1: Significant Presenting History and Symptoms by Subject (●), Dark-Haired Males are Signified by (●)
addition, patients needing additional assistance in the areas of gross and/or fine motor skills may require evaluation with professionals specializing in this area. Occupational therapists, developmental optometrists or other professionals often work with patients displaying deficits in more than one sensory or motor system, aiding the diagnosis of multi-sensory problems and integration of the processes.9

Because of the parent interest in trends related to hair color, each subject was classified as either dark or light-haired. The dark category involved those with dark brown to black hair and the light category those with blonde, light-brown, or strawberry-blond hair (see Figure 1). Hair color is a result of gene expression and related factors primarily, involving KITLG, HERC2, SLC45A2 and OCA2 genes among others.10,11,12 Interestingly, Sterling-Levis and Williams demonstrated a connection between the melanocortin-1 receptor (MC1R) genes and the medical condition Tourette’s Syndrome.13 In addition, there appears to be a connection between melanocortins and a myriad of human diseases including inflammatory response and prolonged and neuropathic pain.12 If hair color is significantly associated with visual information processing performance, then it may be plausible that such disorders are inherited on or near the genes involved in pigmentary expression, a hypothesis well beyond the scope of this study.

Methods

After the receipt of approval from the Ferris State University Human Subjects Research Committee, family subjects were recruited. Eight children and two parents were offered and accepted inclusion in the study. Only the two youngest children were excluded due to age appropriateness of the tests. As an incentive for participation, the parents were offered the Vision Information Processing Assessments (VIPAs) at no charge. Each subject or parent of minor children signed a consent form for study participation. Patients were both male and female, ranging from five to 45 years old. Subjects were assigned a number 1 through 10 from oldest to youngest, with Dad as 1 and Mom as 2.

Testing included a standard Ferris State University Eye Center Vision Information Processing Assessment protocol as described below with additional tests when deemed pertinent, based on history of some subjects. Hair color was also recorded for each subject. All subjects had previous eye examinations within two years and were wearing optimal vision correction at the time of testing.

Each subject was tested individually with the examiner in a quiet room without distractions. The testing was completed in one session, lasting anywhere from one to two hours, depending on the subject responses. Two experienced pediatric optometrists conducted the VIPAs; one doctor tested seven subjects and the other three. Tests were administered in the same order for each child and instructions presented in a uniform fashion as follows: Matching Familiar Figures Test (MFFT), Visual Aural Digit Span (VADS), Letter Sequences (LS) subtest of the Detroit Test of Learning Aptitude (DTLA), Visual-Motor Speed and Precision (VMSP) Test, Beery-Buktenica Developmental Test of Visual Motor Integration (VMI), Developmental Eye Movement (DEM) Test Version 1, Jordan Left-Right Reversal Test 3rd Edition Level 1, Sentence Copy Test, Test of Word Reading Efficiency (TOWRE), Dyslexia Determination Test (DDT), Peabody Picture Vocabulary Test (PPVT) 3rd Edition, and persistent primitive reflex testing for the Moro and Asymmetric Tonic Neck Reflex (ATNR).
The MFFT is a test of visual attention and discrimination performed by asking the patient to choose one of six pictures that exactly matches the given picture. The patient is allowed up to six tries, and the time to make the first response is recorded. There are 12 test items.

The VADS is a number memory test with four subtests, examining visual and auditory memory as well as oral and written expression of memory. The first two subtests have six sets of random number sequences, increasing from two numbers to seven, the second two subtests have five sets of numbers, increasing from three to seven number sequences. The subject is allowed two failed attempts at each section before it is discontinued.

The DTLA Letter Sequences test requires the subject to memorize a sequence of random letters for five seconds and then wait five seconds to record a written response. There are 12 items, starting with two letters and ending at eight letters. The subject completes the whole test, even if errors are made along the way.

For the VMSP tests the subject has exactly two minutes to fill in as many circles with x’s as possible using a pencil, being careful not to go outside the circle limits.

The Developmental Test of VMI requires that the subject copy 24 pictures onto a separate sheet of paper without a time limit or erasing.

The DEM test has three subtests, with two vertical components and one horizontal component. The subject is instructed to read the listed numbers as fast as he or she can, and the results are timed. Errors of omission, transposition, substitution, and addition are recorded as well.

The Jordan Left-Right Reversal Test measures the ability to indentify written letter and number reversals by themselves, letters reversed within a word and whole-word reversals. Only Level one was used for our purposes, divided into three portions, one each of capital letters, lowercase letters, and numbers, some of which are reversed. The subject must circle the letters and numbers that are printed backwards.

During the Wold Sentence Copy Test, the patient is asked to copy a sentence while timed, measuring handwriting accuracy, speed and spatial awareness.

The TOWRE has two subtests, consisting of lists of sight words and non-words. The subject has 45 seconds to read as many of the words as possible for each subtest. This test identifies strengths or weaknesses in sight versus phonetic word reading.

The DDT consists of lists of ten words for various grade levels, and is not timed. For the first decoding subtest, the subject is asked to read the given word list quickly and skip the words not known. The section is scored based on whether each word is read eidetically (as a whole word) or if the word is unknown. When the test ceiling of six out of ten unknown words in a grade level is reached, the subtest is discontinued and the subject is then asked to take the time needed to figure out the words that were unknown. The examiner then records whether the non-eidetic words are read by utilizing phonetics or are unknown. A grade level result for word reading is given and the subject is classified as primarily an eidetic, phonetic or “equal” reader. In the second section of the DDT, the subject must write out the alphabet and the numbers one through ten. For the encoding section first subtest, the subject is read ten known phonetic words one at a time and asked to write them on the recording page. The second encoding subtest requires the subject to spell ten unknown words that were both phonetic and eidetic. This portion reveals whether the subject favors sight word memory or phonetic decoding when writing.

The PPVT is a test of receptive vocabulary where the examiner says a word and the subject points to a picture that conveys the meaning of the word. If incorrect, the test continues until a ceiling number of pictures are missed, revealing possible issues with receptive vocabulary.

Lastly subjects were tested for the presence or absence of the most common persistent primitive reflexes, the Moro and Asymmetric and Tonic Neck Reflexes using the duck/pigeon walk and head rotation techniques (see Figure 2). Retained primitive reflexes may impede proper motor development and posture. For all tests, results were scored appropriately by the examiner after releasing the subject and compared to normative data based on those of the same age or grade.
Table 2: Visual Information Processing Assessment Results by Subject

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<th>10</th>
<th>Avg Dk</th>
<th>Avg Lt</th>
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<tbody>
<tr>
<td>Age (years, months)</td>
<td>44.9</td>
<td>45.4</td>
<td>22.11</td>
<td>20.5</td>
<td>14.8</td>
<td>12.10</td>
<td>9.9</td>
<td>7.5</td>
<td>7.5</td>
<td>5.6</td>
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<td>Sex</td>
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<td>Hair</td>
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<th>Persistent Primitive Reflexes</th>
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<tr>
<td>Jordan R/L (At or Below Grade Level)</td>
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**Table 3: Comparison of Standard Scores and “Z” Scores of Dark-Haired vs. Light-Haired Individuals***

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<tr>
<th>Dark Hair</th>
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<tr>
<td>VMI</td>
<td>68</td>
<td>86.33</td>
<td>78.75</td>
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<tr>
<td>DEM Vert</td>
<td>73.5</td>
<td>85.4</td>
<td>95.25</td>
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<tr>
<td>DEM Horizontal</td>
<td>95.25</td>
<td>90.8</td>
<td>68</td>
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<tr>
<td>DEM Errors</td>
<td>35</td>
<td>68.3</td>
<td>104.5</td>
</tr>
<tr>
<td>Letter Sequences (Modified)</td>
<td>76.33</td>
<td>78.5</td>
<td>76.33</td>
</tr>
<tr>
<td>PPVT</td>
<td>79.67</td>
<td>79.25</td>
<td>95.25</td>
</tr>
<tr>
<td>TOWRE Phonemic</td>
<td>79.67</td>
<td>79.25</td>
<td>95.25</td>
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</table>

Average Standard Score (SS) Dark Hair vs. Light Hair

Average “Z” Score Dark Hair vs. Light Hair

*Tests Averaged Without “Unable” Individuals
level. For the results with normative data ending at a younger age or grade level than the subject, the score was assigned based on the highest available age or grade level under the assumption that scores should be the same or worse when compared to those of appropriate age or grade level. Results were analyzed and reports of the pertinent history, summary and recommendations for remediation were compiled, given to and discussed with the parents and/or adult children. A spreadsheet was created to interpret and analyze the data.

**Results**

Results are best summarized in Tables 2 and 3 but significant scores are described here. Most scores are expressed by a “Z” score or standard score (SS), normal or average values being -1 to +1 and 85 to 115, respectively (one standard deviation below the mean to one standard deviation above the mean). Scores discussed as “below average” are between 1 and 2 standard deviations below the mean and scores discussed as “well below average” are less than 2 standard deviations below the mean. The Letter Sequences test has an average standard score of 10 since it is a subtest in the Detroit Test of Learning Aptitude battery. For comparison purposes in Table 2, subject scores have been multiplied by ten.

For many of the tests, our subjects fell outside of the age range of the normative data but were tested regardless under the assumption that those older than the highest norms table should perform the same as or better than the maximum table value and those younger than the lowest norms table should have performed the same as or worse than the minimum table value. Results are summarized here, denoting subjects that fell outside of the normative range at the time of testing.

The MFFT norms range from five to 12 years old, the Jordan from 5-0 to 12-6, and the VADS norms range from ages 5-6 to 12-11. Subjects 1 through 5 are all older than 12 years 11 months and thus outside of this range. The Letter Sequences norms range from ages 6-0 to 17-11 and the DEM ranges from 6-0 to 13-11. Consequently subject 10 is younger and subjects 1 through 4 are older than the comparable norm tables. The VMI norms range from ages 2-0 to 18-11 and norms for the VMSP range from ages 5-0 to 14-11, so subjects 1 through 4 are older than the highest norm table. The TOWRE norms range from ages 6-0 to 24-11, thus subject 10 is younger and subjects 1 and 2 are older than the closest comparable norms. The DDT norms range from primer to college level, and those older than 20 were scored at college level. Finally, the PPVT norms range from ages four to 90, allowing all subjects to fall within the norm tables.

On the MFFT assessing attention style and visual discrimination, all subjects except subject 10 tended to be impulsive. The most impulsive were subjects 2, 3, 4, and 8 with Z scores of -3.73, -1.71, -2.78, and -1.11, respectively. Subject 4 was inefficient at visual discrimination skills (Z= 2.36). All other subjects were average or slightly efficient.

The next area assessed was visual and aural memory. For the VADS total score, subjects 4, 5, 8, and 9 scored well below average for their age with scores of -2.2, -3.14, -3.84, and -2.31. Subject 10 scored well above her age group norm with a score of 4.95. All other subjects were within the normal range for their age group, however, subjects 1 through 5 were older than the normative database. We can assume that they are slightly lower than reported based on this fact (for all VADS testing). For both aural input and oral expression, subjects 3, 4, 5, 8, and 9 all scored well below the age-expected norms. On visual input, subjects 4, 5, 8, 9, and 10 scored well below average and for written expression, subjects 5, 8, and 9 were well below. All subjects scored below average for the letter sequences, even those older than the maximum norms. Subjects 3 and 9 scored an 8, but all other subjects scored anywhere from 2 to 7.

In the areas of fine motor and visual-motor integration skills, the family also scored poorly overall. On the VMSP number correct calculation, subjects 2, 4, 5, and 8 all scored well below the expected age norms with Z scores of -3.00, -2.05, -4.57, and -2.02, respectively. Because the scores for many of the subjects were so far below the expected range on both the number correct and the number completed, the ratio calculation was affected and does not provide useful information. The VMI was another challenging area for the family, and subjects 2, 3, 4, and 5 scored well below average with standard scores of 52, 62, 52, and 75, respectively. Subject 9 scored slightly below average with an 83. Her twin and all other subjects scored within the average range of 85 to 115. All subjects except subject 7 demonstrated positive persistent primitive reflexes, specifically, the moro and asymmetric tonic neck reflex.

The DEM was another difficult area for all subjects except 2, 3, and 10, as the others scored below average.
(subjects 1, 4, 9) or well below average (subjects 5, 6, 7, 8) for the vertical component. Although subject 10 was able to complete the vertical component, she was unable to complete the horizontal component. She is also outside of the normative database for this test because of her young age. Subjects 2, 3, 5, 8, and 10 scored well below average for the horizontal component with standard scores of 67, 70, 67, 70, and “unable to complete”, respectively. Subjects 6 and 7 scored slightly below average with scores of 81 and 82. Only subjects 5, 7, 8, 9, and 10 made significant errors, however, with scores of 76, 78, 83, 83, and “unable to complete”. This test may aid in diagnosing oculomotor/tracking problems and/or decreased central visual processing speed.

The final areas tested were vocabulary and reading. Tests in this area included the PPVT, the TOWRE, the DDT, and the Jordan Left-Right Reversal, Part One. With the PPVT, all subjects scored within the norms expected for age. All subjects were also within scoring norms for this test and it was a noted area of strength for the family. For the TOWRE sight words, subjects 1, 3, 4, 5, and 7 fell below average with standard scores of 84, 79, 77, 58, and 64, respectively. For phonetic words, subjects 3-7 scored below normal with standard scores of 84, 81, 63, 74, and 74, respectively. Subjects 1 and 2 were older than the maximum scoring norm for this test, and subjects 8, 9, and 10 were unable to complete either portion of the test because they were non-readers. This trend continued with the DDT. Subjects 1, 4, 5, and 7-10 scored below their grade level, with subjects 8-10 unable to read any of the words. Results of decoding and encoding approaches are included in the tables for completeness, but are beyond the scope of this study. All subjects except subject 3 also scored below the expected age level for the Jordan Right- left reversal test, missing anywhere from 1 to 14 letters. Performance may actually be worse than reflected since subjects 1-5 are older than the maximum available norms. Subject 10 was unable to complete the test due to lack of letter identification knowledge.

Discussion

As expected, test results varied amongst family members, although some interesting patterns emerged. When examining data from the dizygotic twins (subject 8 and 9) similar trends were noted in many areas, although the dark-haired male tended to score lower than the light-haired female. Both tested below average on all areas of the VADS, Jordan, DEM vertical and errors, and both were unable to complete several areas of the reading testing in the TOWRE and DDT. The light-haired female scored average on the DEM horizontal, VMSP number correct, and Letter Sequences, while her twin scored below average in these areas. The dark-haired male scored average in VM, while his twin scored slightly below average. Both scored average in the areas of the VMSP ratio, PPVT, and MFFT. The striking similarity is interesting in dizygotic twins with varying levels of birth complications. Female subject 9 was breech, suffered from greater oxygen deprivation and spent longer in the neonatal intensive care unit compared to male subject 8 who demonstrated greater visual processing deficits overall. While genetically they no more similar than any two siblings, they were raised in the same home/school environment with virtually the same schooling at the same ages. This calls into question the possibly larger role of environmental influence.

There are also interesting trends when comparing light and dark-haired individuals. On the VADS, with the exception of the parents who both scored average overall and on all subsections, the light-haired individuals scored better than the dark-haired individuals overall and on all subsections except oral expression which was nearly equal. Of the four subjects scoring well below average overall, three were dark-haired males, and the last, although a light-haired female, was a twin of one of the dark-haired males. Although the light-haired twin scored well below average, she scored significantly better than her dark-haired twin counterpart. On the Letter Sequences, although all scored poorly, it was two light-haired subjects who scored only slightly below average. The same was true for the DDT, where two of the three individuals who scored “at” their grade level were light-haired. For the VMSP and Jordan, again, those who scored at or slightly below average were light-haired, while the dark haired individuals scored below or well below average. For the other tests, data are scattered and is best summarized in Tables 2 and 3. These results lead to questions about the localization of the genes regulating hair color in relationship to those regulating visual information processing currently unidentified. For instance, the dark-haired mother’s results were similar to those of her dark-haired sons. Genes for pigmentary expression contained and expressed on the X chromosome may be housed in a chromosomal location similar to those
regulating visual information processing. Perhaps there may be a deficiency in a common protein pathway regulating pigmentation expression of hair color and visual information processing.

When looking at trends between male and female family members, trends associated with gender were similar to those associated with hair color. Although all female children were classified as light-haired, one male child also met this classification. Results seemed to vary more significantly for the female subjects, but they scored better overall than the group comprised of male subjects, with the exception of the one light-haired male child. Male scores were compared to male norms and female scores to female norms in tests designating the separation. Males tended to score the lowest on the eidetic portion of the TOWRE. It is plausible that because all female children happened to be light-haired and all but one male child happened to be dark-haired, the apparent trends relating to hair color may actually be gender trends. This possibility is complicated by the dark-haired mother and light-haired father, whose results appear more similar to hair color group than gender.

Since there were only two subjects who had light hair and were males, this group was analyzed separately for apparent trends. One of the subjects was the father of the family and the other a son. Interestingly, this father-son duo shares many personality similarities, interests, sports-related skills and symptomatic academic and reading difficulties, as reported by the mother and subjects themselves. Results here were fascinating, based on the fact that both father and son had had different levels and types of education and differed greatly in age. However, results across all tests were surprisingly similar. Both showed persistent primitive reflexes, scored below average for the Jordan, and scored borderline low on the VMI test (the father’s actual score is expected to be lower, as he was older than the oldest norm range for the test). Both scored within average for the VMSP correct and ratio, and both were slightly impulsive for the MFFT. In addition, they were average for all VADS testing, but scored significantly lower on the Letter Sequences. They were below average on the DEM vertical score, and eidetic and phonetic portions of the TOWRE. Both were well below the expected grade level for reading via the DDT. The only areas not showing similarities for these two individuals were the DEM horizontal and errors portions, where the son scored slightly below average and the father scored average, calling into question the role of life experience and age on those results.

The results were additionally analyzed for association with birth complications, since 6 out of the 10 subjects had a positive history, including swallowing meconium, oxygen deprivation, probable use of forceps or vacuum, and the umbilical cord around the neck. No specific associations were found independent of trends applying to the whole family.

There was a positive relationship between test results and subject symptoms as reported by the mother and subjects. When comparing results to symptoms from Table 1, subjects 4, 5 and 8 (all dark-haired males) had the largest number of symptoms and the poorest overall test results. Subjects 1 and 7, the father and son who share light hair and have many commonalities in interests and personality, had identical symptoms (except for premature birth of the father) in Table 1 and shared similar VIPA test results. Subject 3 with diagnosed and symptomatic auditory processing difficulties scored poorest on VADS aural input and oral expression subtests. Subject 1, the father, with self-diagnosed “learning disability” avoids reading tasks. He scored below average on the Letter Sequences, Jordan Reversal, MFFT effectivity, DDT, TOWRE sight words, and DEM vertical and borderline-average for the TOWRE phonetic portion, all relating directly or indirectly to required reading tasks. Although all other areas were within average, it is important to note that on most of the tests he was well above the scoring norms, so standard scores and Z scores are likely artificially high. For subject 2, who has difficulties with drawing, it is not surprising that her VMI was significantly below average, as well as the VMSP, especially considering that she is also far older than the oldest norm age range for those tests.

In regards to the school-age children, all were noted as performing poorly in the home-school environment, especially in reading and pre-reading skills. Results vary by child, but those who were performing “worse” in school and who were the biggest academic concern to the mother all tended to score lowest on the testing as an overall trend.

Issues are present with visual processing, primitive reflexes and tracking in this family, among others not fully explored by this study. When examining the heritable versus environmental influences, it becomes difficult to make any clear conclusions. In terms of inheritance patterns in their children, subject 1 (father) and subject 2 (mother) have similarities in
their memory scores, positive primitive reflexes, and developmental tests with the exception of the mother additionally struggling with fine-motor/visual-motor integration, making inheritance more likely than if merely exhibited in one parent. The father struggled to a larger extent with reading-related testing, such as the DDT, TOWRE and central processing speed of the vertical DEM, whereas the mother struggled more with tracking on the horizontal DEM. On each test in which a child performed below or well-below average, at least one of the parents did as well, with the exception of the VADS, MFFT effectivity, DEM errors and TOWRE Phonemic, on which all but the latter the parents were significantly older than the oldest age norm.

Neither parent was home-schooled and each was raised in a unique environment. It is logical to wonder whether the difficulties emerging in the children have an inherited basis. On the other hand, the rearing of the children in the same home environment with the same parents explains the possible influence of extrinsic environment. Subjects 3 and 4 were the only children who attended school outside of the home for a period of time, although brief, during the formative early elementary years. These subjects display many difficulties with visual processing, tracking and reading skills as well as their siblings, once again supporting a heritable influence. In addition, the study outcomes on the seeming trend between dark hair and visual processing problems lend support to a heritance model, although it is entirely possible that this result is coincidental.

It is equally possible that the skills and attributes of the parents influence the family and learning environment so as to extensively groom the same skills and attributes in the children unintentionally. Or perhaps it is a combination of both. The nature versus nurture argument continues in yet another facet of human development, the visual system.

R.M. LeBel et al. describe the mirror neuron system (MNS) as a player in a child’s ability to observe and copy the skills and behaviors of others. A neural system such as the MNS may provide a possible explanation for inherited tendencies and environmental influences. The results of this study indicate the need for future research on a possible heritable link in visual processing, tracking and gross-motor developmental disorders, and a possible relation to the inheritance of hair color.

Limitations

There were several limitations to the study. The first was a broad experimental test selection, providing a larger quantity of data rather than a more specifically-focused project. It is difficult to determine whether or not difficulties in certain tested areas are overlapping.

It is also difficult to determine whether the results of the study clearly indicate a heritable link with familial visual processing disorders, given that all children were home-schooled most or all of their academic careers in the same way by their mother, who demonstrates some similar visual information processing difficulties.

Although good normative data were available for many of the tests, there were several subjects whose age fell outside of the test-provided norms. Inferences can be made about those findings, for instance, whether the actual data are expected to be higher or lower than the norms indicate, but there are no exact scores for comparison.

The large amount of variables and small number of subjects make it difficult to form conclusions about the relationship between hair color and visual processing skills. At best, the research opens additional questions that may be addressed with a more focused study.

The preexisting oculomotor and binocular issues of the subjects may have also had an impact on the VIPA. Many theories suggest that visual processing cannot develop correctly without proper visual input. It is entirely possible that the co-existing convergence insufficiency, intermittent exotropia and/or tracking problems negatively influenced the VIPA results. These underlying issues had not yet been addressed in a therapy program for the majority of subjects. It would be ideal to compare these subjects to a similar family with vision processing difficulties but normal oculomotor and binocular systems to rule out the possible influence of underlying issues.

Finally, optometric vision therapy had begun on four of the children for tracking, binocular and mild accommodative deficiencies before the VIPA testing was performed. The fact that some of the subjects were familiar with the examiners and had spent time with them prior to the VIPA testing may have had an effect on their testability. There were also 3 subjects who had undergone several sessions of optometric vision therapy at another office before the VIPA testing.
Conclusion

The incidence of visual processing disorders in this family is dramatic and calls into question the possibility of a common etiology for their afflictions. A battery of visual processing, oculomotor and persistent primitive reflex testing has provided a wealth of clinical data to consider the question of nature versus nurture.

Evidence supporting a common heritable factor in this family include: the sheer magnitude of the incidence of visual processing disorders, oculomotor problems and persistent primitive reflexes, common patterns representing areas of strength and deficit, and the association of hair color, particularly remarkable in the dark-haired males and father/son light-haired males.

Environmental influences may also be contributing, based on the consistent home and educational setting. The employment of ineffective strategies and experiences impeding optimal perceptual development cannot be ruled out by this study.

Further investigations into the neurological structures and pathways involved in visual information processing disorders and their heritability are indicated, particularly as they relate to gender and hair color. Additionally, further case studies of monozygotic twins and/or other sibling relationships that demonstrate similar perceptual deficits but who have been educated in different environments may be helpful.

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References

Note: URLs are functional hyperlinks to Internet addresses.