Description of a Novel Model and Method of Assessment of Visual Information Processing Skills

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EXECUTIVE SUMMARY

Visual Information Processing Skills are necessary to obtain meaning from visual input. We propose an update to existing models which allows more clinical utility to practices involved in the treatment of these skills.

INTRODUCTION

Visual Information Processing Skills (VIPS) can be considered the ability to interpret and understand visually presented information and to combine that information with other systems in order to meaningfully interact with the world. Within optometry, this ability is classically discussed in the context of ideas presented by Skeffington and represented by four circles. The four circles are centering, identification, anti-gravity, and speech-language. Vision emerges from the confluence of these four domains. Historically in optometry, the assessment of VIPS has been pursued through a variety of tools, including but not limited to the Detroit Test of Learning Aptitude, the Test of Auditory Analysis Skills and Test of Visual Analysis Skills, the Test of Visual Perceptual Skills, the Monroe Visual III, and the Beery Buktenica Developmental Test of Visual Motor Integration. The Skeffington model has been an excellent guiding concept behind addressing VIPS. There are, however, some limitations to the model and current assessment techniques.

To comprehensively assess a patient's VIPS, each category of processing should be probed.[1] Representing a patient's skills under the Skeffington model defies an easy approach because the tools used within optometry to assess VIPS fail to comprehensively evaluate all areas of the model. Second, although it is implied, the model does not explicitly address the role of memory and experience in processing novel visual information. Attempts to address these issues have been made previously, such as the battery advocated by Scheiman and Gallaway.[2] Their proposed battery can test to a maximum of 15 years of age and has tests that are no longer valid after 8 years of age. This means it cannot be applied to a significant percentage of the population. These limitations have been previously addressed to a degree.

Groffman and Solan advocated for a battery of testing that did explicitly include memory and covered VIPS extensively.[3] They also promoted the concept of a dichotomy, or forced choice, within a realm of processing. Specifically, they determined whether a patient processed better sequentially or simultaneously. We feel this is a powerful concept, but it should be extended beyond a single domain. Additionally, their battery was also limited to pediatric patients due to the testing instruments selected.

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We had several additional goals in developing our current model of processing. Currently, while practitioners can seek to make some modifications to therapy based on processing performance, this is largely left to the intuition of the individual practitioner. We believe that our model allows specific modifications of any activity to address specific VIPS weaknesses, allowing us to tailor therapy more precisely. Second, we felt that there was a better way to express strengths and weaknesses, both to other practitioners and to patients. Most testing batteries report a score and an interpretation of that score, whether as a stanine, percentile, or age equivalence. We feel we have developed a more intuitive presentation method than a list of scores. Finally, we believe we should be able to know reasonable goals and treatment timelines prior to commencing therapy. None of the current tools of assessment reliably project the effect of vision therapy on VIPS performance.

With these limitations and goals in mind, we have sought to develop a new model and battery of VIPS assessment aimed at addressing these weaknesses. This paper will describe the model developed, list the currently associated tools of assessment, and convey the advantages such a model possesses.

Description of Model of Visual Information Processing

Within our model, a patient's abilities in four major areas and up to six domains are evaluated. Each of the four major areas includes a number of subskills with which optometry is familiar (Table 1). The domains utilize forced-choice sorting of the tests given. Patients are given standardized assessments of processing skills gleaned from numerous professions, including optometry, occupational and physical therapy, speech and language pathology, education, and neuropsychology. We were careful to select batteries with good normative statistics including a broad range of discriminative ability and test-retest reliability. Our current approach consists of six different sets of tests based on the age of the patient (Table 2). The testing batteries we currently select from are listed in Table 3; however, one strength of this assessment technique is that any statistically appropriate standardized pro-

Table 1: Major Areas and Subskills

1. Identification/Discrimination
- a. Form Perception
- b. Form Constancy
- c. Discrimination
- d. Classification
- e. Figure/Ground
- f. Visual Closure

2. Spatial Awareness
- a. Distance Judgement
- b. Size Judgement
- c. Area Judgement
- d. Volume Judgement
- e. Egocentricity
- f. Spatial Relations
- g. Sequentialization
- h. Directionality
- i. Orientation

3. Visualization
- a. Imagery
- b. Working Memory
- c. Delayed Memory
- d. Long-Term Memory
- e. Spatial Memory
- f. Recall
- g. Recognition
- h. Manipulation

4. Visual Integration
- a. Body Scheme Awareness
- b. Laterality
- c. Bilateral Integration
- d. Visually Guided Movement
- e. Visual/Vestibular Integration
- f. Eye/Hand Coordination
- g. Visual/Tactile Integration
- h. Visual/Auditory Integration
- i. Visual/Verbal Integration
- j. Visual/Temporal Integration

Table 2: Testing Batteries and Valid Ages

Test Battery	Valid Age Range
Readiness	4 years, 6 months to 7 years, 0 months
Elementary	6 years, 6 months to 11 years, 6 months
Middle School	11 years, 0 months to 14 years, 6 months
High School	14 years, 0 months to 19 years, 0 months
Adult	18 years, 6 months to 60 years, 0 months
Geriatric	Over 59 years, 6 months

Table 3: Current Testing Instruments

Universal Non-Verbal Intelligence Test
Peabody Picture Vocabulary Tests
Detroit Test of Learning Aptitude – 4th edition
Tests of Memory and Learning – 2nd edition
Tests of Memory and Learning – Senior Edition
Comprehensive Trail-Making Test – 2nd edition
Goodenough Draw-A-Person Test
Token Test for Children – 2nd edition
Test of Nonverbal Intelligence – 4th edition
Comprehensive Test of Phonological Processing – 2nd edition
Leiter-R
Test of Gross Motor Development – 2nd edition
Bruininks-Oseretsky Test of Motor Proficiency
Comprehensive Test of Nonverbal Intelligence
Structure of Intellect
Birch-Belmont Auditory-Visual Integration Test
Test of Information Processing Skills
Wide Range Assessment of Memory and Learning
Shipley Vocabulary Test
Beery-Buktenica Developmental Test of Visual Motor Integration

cessing battery with a high degree of visual involvement can be inserted into the model. We feel this allows the inclusion of new assessment tools as they are developed. If the exact battery of tests we are currently using becomes commonly administered within optometry, it should be independently validated.

Pediatric batteries generally report an age equivalence based on patient performance. For these batteries, a perceptual quotient (PQ) is calculated for each subtest by dividing the patient's chronological age into the age equivalence. This is the method commonly used for patients ranging from 4 years to 14 years of age and controls for gains over time due to normal development. Batteries designed to assess teen and adult performance generally report a Standard Score (SS). These tests are rescaled to a mean of 100 and a standard deviation of 10 and the new SS is reported. Once the full battery is administered the patient's PQ or SS for all tests is averaged to give an overall ability.

The tests are then evaluated for inclusion into the four major areas. If performing a particular test requires a major skill, that PQ/SS is included within that major area. The results are then averaged to provide an ability within each major area. The four main areas explored are identification, spatial awareness, visualization, and integration. Detection of relative weakness within a major area, i.e. performance substantially poorer than that demonstrated on the overall ability, allows tailoring of activities to the specific weaknesses of the patient.

The tests are further sorted into dichotomies, or a forced choice between opposite processing styles, of various domains. While the analysis of the battery treats these domains as exclusive, we recognize that most patients fall somewhere between the two extremes. For example, a patient rarely processes information in a completely verbal or a completely non verbal fashion. A patient would ideally be balanced between the two branches of each dichotomy. If a particular test does not fall sufficiently to one extreme of the continuum within a domain, it is excluded from the analysis of that domain. Scores from each division of the dichotomy are averaged and the two scores are compared. Highly significant differences within each dichotomy (indicated by a skew of more than 10 points) are noted. Skews in performance implicate a particular weakness and possible coping strategies to overcome that weakness. This in turn allows us to infer typical characteristics of the patient. The domains, skews, and interpretations are as follows:

1. ***Cognitive Domain: Manipulative vs. Associative Divisions***
   Manipulative thinking ability involves the abilities of problem solving, thinking in abstract terms, and manipulation of mental images as if viewing from another perspective. *Associative* thinking ability explores the individual's aptitude in dealing with physical properties such as form, texture, size, location, orientation, and sequence.

If Manipulative is significantly greater than Associative:
This skew in performance represents an individual with greater potential than performance in visually related tasks. Reasoning ability is significantly greater than visual performance, possibly due to inadequate visual information acquisition skills. This individual often utilizes intellect to manipulate situations in order to avoid demonstrating weakness in visual performance or will spend more than the expected time on visually related tasks to avoid or to sort through mistakes to eventually arrive at an appropriate response.

If Associative is significantly greater than Manipulative:
This skew in performance is often seen in individuals who are somewhat more detail oriented, concrete thinkers able to organize tasks rather than to be expected to initiate a plan to solve a given problem.

2. ***Linguistic Domain: Verbal vs. Non-Verbal Divisions***

Verbal abilities use and depend on expressive or receptive language while performing a visual task. *Non verbal* abilities relate to performing visual tasks that do not involve reading, writing, or verbalization.

If Verbal is significantly greater than Non-verbal:
This skew in performance usually represents an individual who, as a coping strategy, relies heavily upon verbal skills to perform appropriately, and will usually benefit from being able to (or may need to) verbalize experiences. If a patient's Verbal score is 100 or greater and this skew is accompanied by good intellectual potential, the individual is frequently an "auditory learner".

If Non-verbal is significantly greater than Verbal:
This skew in performance is usually exhibited by individuals who are better at "hands on" manipulative tasks rather than tasks that involve reading, writing, or verbalizing experiences.

3. ***Attentional Domain: High Attention vs. Low Attention Divisions***

In *high attention* tests, the emphasis is to require greater focused attention and concentration. If attention wanders during a task, the individual's performance is negatively affected. *Low attention* tests have minimal demand for sustained, focused attention and concentration, and thus if attention wanders but one can bring oneself back to task, the test score is not affected.

If High attention is significantly greater than Low attention:
This skew often relates to an individual who, while willing and frequently able to give attention to a given task, if interrupted for whatever reason oftentimes finds it difficult to return to the task and finish it. These individuals often have numerous unfinished projects.

If Low attention is significantly greater than High attention:
This skew in performance usually implies significant attention problems: difficulty sustaining focused attention and involvement on visually demanding tasks; is often easily distracted; and has difficulty completing tasks on time.

4. ***Motoric Domain: Motor Involved vs. Moter Free Divisions***

Motor involved activities require the ability to use the visual system to guide the motor system in fine motor or gross motor tasks. *Motor free* activities are those that do not involve motor ability as a major component in completing a task.

If Motor involved is significantly greater than Motor free:

This skew in performance usually represents an individual who relies upon kinesthetic/tactile reinforcement of visually presented information. This individual is often observed picking up, touching, or petting everything in sight. Performance is usually better in "doing" related courses or activities. These individuals are often good in sports but are selective and rather predictable in positions or sports played. They can often put together and take apart equipment, but have a difficult time reading or following the instructions.

If Motor free is significantly greater than Motor involved:
This skew in performance represents difficulty in areas related to eye-hand coordination, handwriting, balance, coordination and posture. Performance in visually directed motor activities is usually below the individual's otherwise demonstrable potential.

5. ***Processing Style: Simultaneous vs. Sequential Divisions***
Simultaneous processing involves addressing multiple stimuli at once and integrating them to produce the appropriate solution. *Sequential processing* involves the ability to take in, store, and process information in a serial or temporal manner in a step-by-step approach, with one element of the task leading to the next in an orderly fashion.

If Simultaneous is significantly greater than Sequential:
This skew in processing usually represents an individual who performs well with problems requiring creative problem solving or grasping of ideas. Abilities which may be below expected potential would include activities such as memorization of number facts, associating letters and sounds, understanding the chronology of historical events, steps involved in the procedures of basic math (e.g. "borrowing") or following scientific methodology. They are often able to see the result better than the steps needed to reach that result and tend to be more idea oriented than detail oriented.

If Sequential is significantly greater than Simultaneous:
This skew in processing usually represents an individual who can analyze problems if there is an orderly sequence to them, but has difficulty grasping concepts if several stimuli are presented at once. Accurate judgment of space and form may be difficult if not given a longer than ordinary amount of time to relate this information to something already known. They tend to be more detail oriented than ideational. They usually see the individual components of a task, try to arrange them successively, and stay with a task to completion. Other abilities that may be impaired are creative problem solving, deriving meaning from pictures and other visual stimuli, and being able to comprehend the main ideas or underlying meanings of stories or complex mathematical principles.

6. ***Reasoning Ability Domain: Fluid vs. Crystal***
Fluid reasoning ability is the capacity to reason, form concepts, think logically, and solve problems in novel situations, independent of acquired knowledge. *Crystal reasoning* ability utilizes the depth and breadth of general knowledge that has been gained as a result of education and cultural experiences.

If Fluid is significantly greater than Crystal:
This skew in performance implies an individual whose creativity is limited by a lack in basic store of knowledge, facts, and experiences. They typically need additional sources to provide facts and information.

If Crystal is significantly greater than Fluid:
Individuals with this skew in performance tend to perform better on rote memory tasks than on those tasks which involve

adaptations to change or creativity. They also often perform better on tasks of reading comprehension than math or problem solving.

Advantages of Adopting This Model

This model addresses many of the weaknesses of typical VIPS testing in optometric practice. As currently administered, each main area of VIPS and each division of the dichotomies is tested by a minimum of three tests that have been independently developed and validated. We believe this strikes a balance between unnecessarily testing the patient and not allowing exceptional performance on a particular test to unduly affect the overall profile.

Secondly, this model explicitly addresses the role of memory and experience within the visualization area. It is even further broken down into short-term, long-term, and working memory, allowing us to screen for neurological concerns. For instance, intact long-term memory with significantly impaired short-term memory in a geriatric patient might prompt referral to a specialist in dementia and atypical cognitive decline.

Furthermore, the model expressly illustrates other interprofessional consultation considerations. For example, if a patient demonstrates a skew in the linguistic domain with low performance on verbal tests, evaluation with a speech and language pathologist may be warranted. If the patient demonstrates a skew in the attentional domain with poor performance on the high attention tests, evaluation with a neuropsychologist trained in the treatment of ADD/ADHD may be warranted. Should vision therapy be pursued and such a skew is recalcitrant to visual interventions, i.e. it fails to improve or widens, such consultations are more strongly warranted. We have identified at least seven patterns that would warrant consideration of consultation with a comanaging professional from a different field, such as Occupational Therapy, Physical Therapy, Neurology, Psychology, Audiology, and Speech and Language Pathology.

The existence of skews within a VIPS graph provides clues on effectively programming specific activities as well as ways to modify visual information acquisition activities (e.g. Brock string, Hart chart, etc.) to address weaknesses in processing. In this way, the therapy program can be specifically tailored to the individual patient. This provides two benefits. First, it allows us to target a program to maximize the effect on VIPS. Second, by working on demonstrated weaknesses in acquisition and processing simultaneously, we are engaging more diverse cortical areas which should provide better retention and generalization of skills once therapy is completed.

Additionally, this model allows us to have some prognostication regarding the effectiveness of vision therapy on VIPS. In our experience, patients generally demonstrate between 6 and 11 points of improvement on their overall score after three months of active therapy in our program. The model also indicates a minimally obtainable projection of a patient's overall VIPS ability. This is determined by averaging the four highest scores on the main areas or dichotomies. We have been successful in reaching these projections within our therapy program. By analyzing the difference between the initial overall score and the minimally obtainable projection, we can reasonably predict the amount of therapy necessary to achieve that projection. This allows us to estimate the length of time and cost for a patient in advance of beginning therapy. Individual therapy offices could track their typical improvement and modify the time projection if necessary.

Finally, our model is represented graphically (Figure 1). This allows us to quickly ascertain the nature and degree of the processing concerns for each patient. It also makes the patient's initial status and therapeutic gains more intuitively understandable to the patient and any caregivers.

For all of the above reasons, we feel that this model of visual information processing would provide substantial benefits to most offices providing vision therapy.

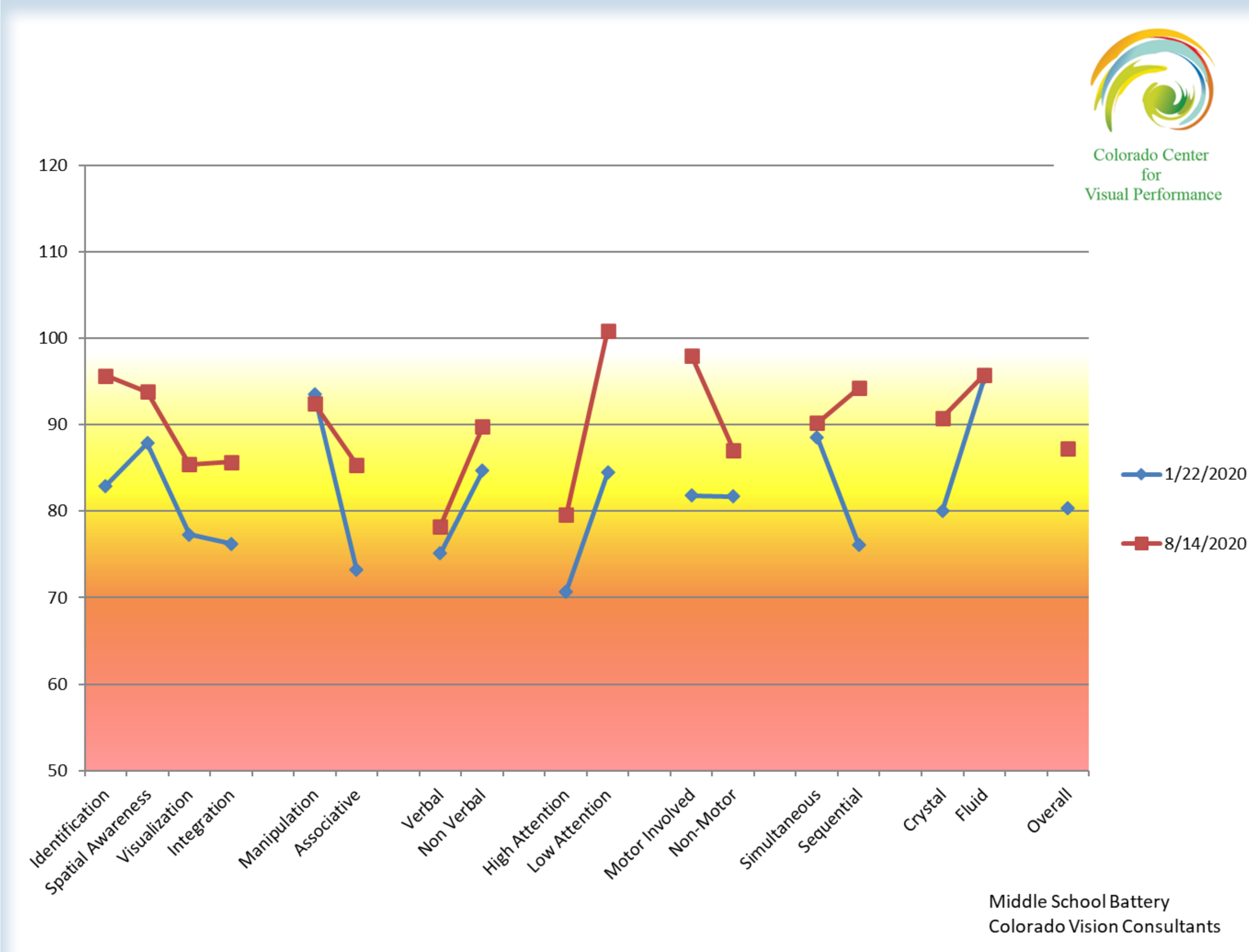

Figure 1. A representative graph of patient performance on our processing battery before and after therapy.

ADDITIONAL COMMENTS

In its current iteration, our testing battery has three different extents of testing. If all tests are given, each battery takes approximately four hours to administer. We call this a comprehensive battery. Every reported major skill and domain is assessed by no less than three independent tests. We sought this number of tests to reduce the chance of one particular test having too much influence within a domain or skill. Thus far, we have been administering the comprehensive battery to all our patients as we have sought to build a data set around this battery. However, we also recognize that four hours is a significant investment of time for an individual practitioner. We have also built into each battery subsets of tests, which we call a diagnostic battery and a screening battery. The diagnostic battery generally takes around three hours to administer. The screening battery can usually be completed in under two hours. In the data we have analyzed thus far, the diagnostic battery has been in overall agreement with the comprehensive battery, although skews within domains are sometimes exaggerated. The screening battery has an occasional reversal within a skew but would allow the testing to be completed in a much shorter time. If the screening battery is being used as the primary assessment tool, a higher degree of intuition will be necessary on the part of the practitioner.

We also recognize that we have pulled from a broad area of tests, some of which are not commonly used within the optometric community. Prior to the administration of this battery or any other standardized assessment, thorough familiarity with specific test administration through the testing manual should be pursued.

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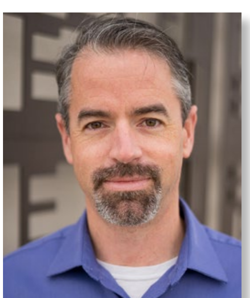

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