ARTICLE

Understanding the Visual Symptoms of Individuals with Autism Spectrum Disorder (ASD)

Rachel A Coulter, OD, FCOVD, FAAO
Nova Southeastern University, College of Optometry

ABSTRACT

Background: Sensory integration problems are frequently found in individuals with Autism Spectrum Disorders (ASD). In particular, vision is often affected with visual symptoms being pervasive and severe. These visual symptoms are due to an individual's unique sensory-processing abilities and are biologically based in origin.

Review: Ninety-six publications, including research studies, case reports, literature reviews and first-hand accounts were reviewed. Visual symptoms in individuals with ASD are linked to underlying differences in the central nervous system including the visual system. The concept of Individual-Differences from the Developmental, Individual-Difference, Relationship-based (DIR) model is discussed with regard to vision. Visual differences for individuals with ASD include photosensitivity, hyper- and hypo-sensitivity, color perception processing, and differences in processing central and peripheral stimuli. Face processing, gaze shifts, visual integration with other senses, and visual closure are affected as well. It has also been noted that motion processing, visual-spatial and visual-motor processing and spatial awareness including visual neglect are also anomalous. Some visual symptoms such as gaze aversion, lateral vision and hand flapping are so intimately associated with ASD, that they are used to screen for and to assist in the diagnose of the condition. A symptom intake form summarizing symptoms associated with these visual differences is provided as a resource.

Conclusions: Understanding the link between visual symptoms and their underlying visual differences is important so that the optometrist who cares for patients with ASD can accurately gather information, complete diagnostic testing, interpret results, choose treatments, educate the patient and his or her caregivers and make appropriate referrals when necessary.

Keywords: autism spectrum disorder, developmental individual-differences relationship-based (DIR) model, face processing, gaze aversion, gaze shifts, hyper-sensitivity, individual differences, sensory processing, stereotypic behavior, visual processing, lateral vision, visual differences, visual symptoms

Introduction

The autism spectrum disorders (ASDs) are a group of developmental disabilities that are characterized by significant impairments in social interaction and communication, as well as repetitive stereotyped behaviors.[1] Individuals who have ASD often are affected in their ability to attend, learn and process sensory stimuli. The term *spectrum* refers to the tremendous variation in how the condition is manifested. For instance, cognitively those with ASD may range from gifted to severely-challenged, from talkative to completely non-verbal, and from performing independently to needing constant one-on-one attention. Symptoms of ASD begin before the age of 3 years and exist throughout an individual's life. ASD occurs in all racial, ethnic and socioeconomic groups and is four times more common in boys than girls.[2]

Correspondence regarding this article can be e-mailed to staceyco@nova.edu or sent to Dr. Rachel A Coulter, Nova Southeastern University, College of Optometry, 3200 S University Dr, Ft Lauderdale, FL 33328.

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Three areas are evaluated for behaviors consistent with a diagnosis of ASD:[3]

- Social Interaction - decreased eye contact, very little facial expression, an inability to develop peer relationships, and a lack of social or emotional reciprocity
- Communication - marked delay in the development of spoken language, being unable to carry on a conversation, very limited abilities to make-believe or show imaginative play
- Repetitive, stereotyped behavior patterns - inflexibility to changes in routine, repetitive motor mannerisms such as lining up objects, and marked preoccupation with the parts of an object rather than it use as a whole

Based upon the history and diagnostic testing, an individual may be diagnosed with one of the ASD conditions. These conditions include autistic disorder, pervasive developmental disorder - not otherwise specified (PDD-NOS, including atypical autism), childhood disintegrative disorder, Rett syndrome and Aspergers syndrome. All of these conditions have some of the same symptoms, but they differ as to onset, severity, and the specific pattern of symptoms.

Public interest and awareness of the needs of individuals who have ASD has increased as the Center for Disease Control has measured a marked increase in the prevalence of the condition up to 1 out of every 150 children.[4] Recent articles have highlighted the role of optometrists in caring for individuals with ASD.[5,6] These individuals often suffer from symptoms related to vision and visual processing problems. In addition to symptoms caused by uncorrected refractive error, accommodative, ocular motor and binocular problems; autistic individuals have visual symptoms due to differences in visual perceptual/ information processing. Unusual perceptions and information processing, as well as impairments in emotional regulation, have been identified as core symptoms of ASD.[7]

The influx of patients diagnosed with autism presents a challenge to optometrists. This challenge is due to the large numbers of individuals, the varying presentation and needs of individuals given a label of ASD, and the range and intensity of visual issues associated with the condition. In addition, many optometrists who may be experienced in developmental vision and vision therapy may be new to working with this population.

Optometrists who serve these individuals need to understand visual symptoms associated with ASD. Given their long-standing tradition of relating vision problems to their functional impact, they are uniquely positioned to manage these patients. This understanding should include an awareness of visual symptoms often associated with ASD, their underlying biological basis when known, and how they may manifest in individuals who have ASD. Understanding these symptoms is also important so that the optometrist can best choose and implement treatment options that include refractive correction, plus lenses, adds, and yoked prism lenses; as well as colored overlays, colored lenses, optometric vision therapy, and environmental modifications that maximize function in individuals with ASD. Understanding symptoms is important so that optometrists can educate caretakers and ASD individuals themselves as to why these symptoms occur. Lastly, in some cases, understanding ASD associated symptomology may enable optometrists to detect these symptoms in undiagnosed individuals and refer them for an evaluation to diagnose or to rule out ASD.

This article provides an overview of visual symptoms found in individuals with ASD. A review of the literature including published research studies, literature reviews, first-hand accounts and texts on autism has been completed. A discussion of the underlying basis for visual symptoms is provided. Finally, a symptom intake form is included as a resource for gathering information. (See Table 1).

ASD and its associated visual differences

The biological basis of ASD are differences in central nervous system structures including the cerebellum, cerebral cortex, limbic system, and corpus callosum as well as the basal ganglia, brain stem and neurotransmitters found within these structures.[8,9] Given the extent of the neurological underpinnings of the visual system, it is not surprising that a condition with widespread differences in brain function would greatly affect vision function as well. Individuals who have autism *often* have difficulty processing and integrating sensory information including visual information.[10] Research of visual symptoms has shown the symptomology experienced by children with ASD are more severe and complex than those found in children who are developing normally. In a comparison of visual symptoms using the Diagnostic Interview for Social and Communication Disorders

Table 1. Visual Symptoms and Individuals with ASD

Visual symptoms highly associated with ASD
___Gaze aversion
___Turning head, looking out of corner of eye
___Being attracted to shiny surfaces or mirrors
___Prolonged fixating on light patterns, windows or blinds
___Hyperfixating on one object while ignoring other objects in the room
___Always prefers/avoids a particular color
___Shows distorted body postures or orientation including arching back, hyperextension of neck
___Toe walking
___Touches all surfaces (walls, furniture, etc) when in an unfamiliar environment
___Anxiety or avoidance associated with fast moving objects or animals
___Spinning objects close to face
___Intense light sensitivity
___Poor attention to one's surroundings as well as a lack of interest in one's environment
___Preference for looking at objects (or parts of objects) rather than people
Visual symptoms included in the screening/ diagnosis of ASD
___Poor eye contact
___Excessively lines up toys or other objects
___Fidgets with objects repetitively
___Maintains interest in spinning objects for periods greater than a couple of minutes
___Does not follow where someone else is looking
___Walks on tiptoe
___Flicking fingers or hands near face
___Stares at nothing with no apparent purpose
___Excessive interest limited to a single toy

(DISCO) in a group of children with autism and a group of normally developing children matched for age; results determined that children with autism had more visual symptoms and that these visual symptoms were pervasive, multimodal and persistent across age and ability.[11]

Refractive error, binocularity, ocular motility, contrast sensitivity

Like other populations of children with developmental disabilities, children with ASD have higher incidence of refractive error, but the distribution of refractive error does not have a clear-cut trend. Scharre and Creedon studied 34 children who had autism and found that 44 percent had significant refractive error that was defined as myopia equal or more than 1 D, hyperopia equal or greater than 1 D, astigmatism equal or more than 1 D or anisometropia equal or more than 1 D.[12] Studies of ASD populations show a higher incidence of strabismus.[12,13] Scharre and Creedon also found that of the 34 children evaluated 7 (21 percent) had strabismus. Of the seven children who had strabismus, six were exotropic and one was esotropic. In another study, a parent survey of 7,640 families in 1999 found a reported incidence of strabismus of 20 percent.[13] Kaplan, Rimland and Edelson examined 34 individuals with autism and found a 50 percent to have strabismus. Of those with strabismus, 65 percent had exotropia and 35 percent had esotropia.[13]

ASD individuals also have differences in ocular motility function when compared to typical peers. These include atypical optokinetic reflexes at higher target velocities.[12,14] Smooth pursuit performance overall is good, but performance varied among different individuals with ASD.[14] ASD individuals show diminished control of saccades with the result that more saccades occur in response to stimuli and the saccades are hypometric.[15,16,17] ASD individuals show the most dramatic difference on tasks that require that the individual make sequential saccades to stationary targets in a patterned array.[14]

Research of contrast sensitivity in children with ASD showed worse contrast performance on pattern targets, but not in flicker detection. Reduced contrast sensitivity may explain other reported symptoms noted such as experiencing confusion at a change in flooring or stairway.[18] ASD children perceive fine detail, but do not perceive the grating in Gestalt fashion.[19] These results are consistent with other research that shows visual function decreases as the underlying neural circuitry and integration for the task become more complex.

Visual processing symptoms and their basis in individually based biological differences

Individuals with ASD may present with symptoms due to untreated refractive, accommodative, binocular and ocular motility problems. The symptoms that most impact the individual's ability to function and that present the largest challenge to the optometrist are due to more complex visual processing functions. In diagnosing and managing symptoms due to vision processing problems, a helpful idea is the concept of Individual-Differences. To understand the concept of *Individual Differences*, one needs some background information on the DIR model.

Developmental Individual-Differences Relationship-Based (DIR) model

The Developmental Individual-Differences Relationship-Based (DIR) model is a multidisciplinary framework that is useful in understanding how human development occurs in all individuals and especially helpful in understanding challenges in an individual who is developmentally lagging behind their peers. Based upon the work of Stanley Greenspan and Serena Weider, the DIR model is used clinically to enable an individual with developmental delays to organize his or her environment and to stay engaged and interactive.[20] When an individual is able to organize his or her environment and sustain interaction, then he or she can learn and develop. The DIR model has three key parts. The *Developmental* part refers to capacities that humans typically master in their first five years of life. One capacity is the ability to self-regulate, which is to be calm, organized and able to attend to one's environment. Another capacity includes the ability to maintain reciprocal social interaction including back-and-forth communication. Other capabilities include the skills required to form ideas and the ability to engage in complex thinking such as those used in negotiating and understanding another's perspective and to think logically.

These capacities do not develop sequentially, but in order to proceed to higher levels of development, mastery of these areas is required. The *Individual-Differences* part of the model refers to the idea that each individual has a unique biological make-up that serves as the basis for their experience of the world around them. The individual's neurological system may be hyper- or hypo-sensitive to a wide range of stimuli. Their neurological system, as well as his or her temperament and learning style, all interact and influence how the child reacts and responds to sensations, and regulates and understands sensory information. Specifically, this biological make-up results in physiological differences within each individual in auditory processing and language, motor planning and sequencing, regulation, and visuo-spatial processing.[21] Each individual, then, has a unique way of processing information, including visual information, resulting from his or her individual-based differences in central nervous system function. The *Relationship-based* part of the DIR model refers to the learning relationships that the individual has with caregivers, therapists and peers. In the DIR model, caregivers, therapists and peers provide individualized affect based interaction to the individual who has delays to enable him or her to make progress in mastering the fundamental capacities.

Individual Differences and therapeutic interventions for visual symptoms

In the DIR model, any therapeutic intervention or interaction with the individual must respect the individual differences found in each patient. Treatment of a patient's symptoms must include a profile of the individual's strengths and challenges in all areas: auditory processing, language utilization, motor planning and sequencing, regulation, and visuo-spatial processing. Treatment then is based upon multi-disciplinary management that is specific to the individual's sensory-processing profile and emotional development and must occur within the context of meaningful relationships to caretakers and peers.

The optometrist who treats the visual symptoms of an individual with ASD must be aware of their link to central nervous system functioning. We also need to be aware of a particular patient's biological make-up and sensory information processing profile. The concept of individual-differences explains why visual symptoms can vary tremendously between different individuals with ASD. It also explains why differences in vision processing and their associated symptoms and behaviors can occur on a continuum. Finally, it is important to note that the manner in which individuals with ASD process visual information does not always result in deficits of visual processing. In some instances, individuals with autism may process visual information with heightened abilities to attend to visual detail or to remember and process visual memories. The concept of individual-difference when applied to vision, i.e. visual difference, is particularly useful in that it connotes both strengths and deficits.

Visual differences include hyper- and hypo- sensitivities in processing visual stimuli. They also include efficiency/skill and perceptual/processing problems that exist in typically developing children, but may be heightened in individuals who have autism.

Hypo-sensitivity and Hyper-sensitivity

Hypo-sensitivity and hyper-sensitivity to visual stimuli are commonly experienced by individuals with ASD. The parent, caregiver or health care professional may become aware of the hyper- or hypo-sensitivity indirectly by compensatory or avoidance behavior exhibited by the patient. Firsthand accounts provide detailed examples of the intensity and impact of visual disturbances and personalize the statistics and research studies that have been published.[22,23] Individuals with ASD have described experiences in which they experience both visual hyper- and hypo-sensitivity even vacillating unpredictably between both.[7] Difficulties in modulating visual input may be responsible for a number of atypical looking behaviors.[24] Accounts of hypersensitivity include descriptions of increased light sensitivity and harshness of colors.[23,25,26] In other descriptions, individuals may hyper-focus on one object, such as a single poster or a spinning top, but have no awareness of any other object in the room. In yet other experiences, attributes of an object may be exaggerated so that the individual with ASD experiences distortions of depth or stationary objects that are perceived as moving.[7,27] This may even result in misjudging the width or height of an object to the point of resulting in injury.[7] Individuals with ASD have described sensory tune-outs where input of vision may suddenly black-out and then return again.[28]

Some individuals have learned to use their visual hypersensitivities to their advantage by cultivating an enhanced ability to visualize experienced events and to manipulate images associated with these memories in an complex detailed fashion.[7,29] Temple Grandin, an animal science professor who has autism described in her book, *Thinking in Pictures*,

> "When I do an equipment simulation in my imagination or work on an engineering problem, it is like seeing a video tape in my mind, I can view it from any angle, placing myself above or below the equipment and rotating it at the same time… I create new images all the time by taking many little parts of images I have in the video library in my imagination and piecing them together. I have video memories of every item I've ever worked with."[30]

Visual hypersensitivity may also promote superior visual search abilities in children with autism, possibly by heightened feature discriminability or failure to inhibit reception of some information.[31]

Hypo-sensitivity to visual information can also occur as individuals with ASD struggle to regulate their level of alertness, body position, touch and auditory stimuli. When too much information is present, the individual may become overwhelmed or saturated by other stimuli so that they are unable to process visual information.[23,32]

Color perception and hypersensitivity to color

Studies of color perception in children with ASD have demonstrated differences in color memory, discrimination abilities between colors, and detection of color when presented on achromatic backgrounds.[33] Acute sensitivity to color has been widely reported by first-hand accounts and caretaker observations. Individuals with autism have been noted to only eat white foods or to never play with toys of a certain color.[34] To manage these hypersensitivities, clinicians have implemented a variety of interventions including colored overlays, colored lenses and syntonics. Colored overlays have been shown to increase reading speed in children with autism when compared to a control group matched for age and intelligence.[34] First-hand reports state tinted lenses have benefited some individuals.[27] Some practitioners have reported that syntonics, phototherapy in which viewing of certain light frequencies may improve physical and emotional functioning, in individuals with ASD, but research to prove its effect has not yet been completed.[35]

Photosensitivity

Photosensitivity has long been noted to be a symptom associated with autism.[36,37] Of note, up to 50 percent of those who have autism may have severe sensitivity to fluorescent lighting.[38] Researchers found that repetitive behaviors for ASD children increased when they were in a room illuminated by fluorescent light versus when they were in a room with equal intensity incandescent light.[39] Individuals with autism may be hypersensitive to the flicker of the fluorescent lighting with some reports suggesting they can see a 60-cycle flicker.[40]

Differences in visuo-spatial and visual-motor processing

Individuals who have autism have been shown to exhibit differences in visual spatial processing. Those with ASD often struggle to develop appropriate visuo-spatial skills. Some of these visuo-spatial skills include body awareness, locating their own bodies in space, relating objects to self, other objects and other people, as well as higher order visuo-spatial abilities that include conservation of space, visual-logical reasoning and representational thought.[21,41] To compensate for their inability to process visual information in their environment, those with ASD often rely on proprioception.[42,43] Some behaviors exhibited by individuals with ASD include toe walking, hand flapping or flicking fingers near their faces, have been explained as compensations for poor visuo-spatial skills. These individuals are seeking additional sensory input to tell them where they are in space.[44] Therapy programs, such as program detailed in Wachs and Furth's *Thinking Goes to School*, have been used to address the challenges of difficulties in visuo-spatial and visuo-motor processing.[45] Rose and Torgerson reported that they observed progress in their optometric vision therapy (OVT) patients by starting with activities to improve peripheral awareness and attention, along with the use of performance lenses, prior to traditional OVT activities.[46] Though there is a scarcity of research studies of OVT in individuals with ASD; Lovelace et al reported the results of a small pilot study that investigated the feasibility of using vision therapy in children with ASD as part of an interdisciplinary intervention. Their study reflected some of the challenges in providing OVT in this population using traditional approaches. Individuals in the study when presented a traditional therapy task had difficulty performing the task. At times the individuals did not respond, perseverated on an action that was part of the task, or showed frustration.[47]

Spatial awareness

Individuals with autism show deficient levels of attention to visual stimulation.[48] Instead of using the visual information in their environment to provide input, individuals with ASD may use their tactile and kinesthetic feedback. This inability to integrate and process information across sensory modalities results in the affected individual appearing as if they are unaware of people or objects in his/her environment. Difficulties in spatial awareness may impact the person's position in space.[48] Symptoms of abnormal head and body posture have been theorized to be the result of an inability to process spatial information related to oculocentric, headcentric and bodycentric localization.[49,50] Research in individuals with ASD has shown that they have reduced postural stability that begins to improve at age 12 years but does not reach normal levels even by adulthood.[51] Postural instability also increases in these individuals when the task of maintaining postural control requires more complex sensory integration.

The use of yoked prisms in autistic individuals has been shown to improve orientation and posture and visual-motor skills.[52] In Kaplan's investigation of 24 children with autism, Yoked Base-Up and Base-Down prism were shown to improve spatial orientation and body posture and the ability to complete a ball catch activity. These improvements have been attributed to changes in *ambient/global system* processing. Recent research suggests the improvements are linked to enhanced cerebellar-mediated function.[50, 53-55]

Processing of central and peripheral stimuli

The combined effects of visuo-spatial processing differences and visual neglect may result in poorer processing of peripheral stimuli. In a study of visuo-spatial orienting, the performance of high-functioning adults with autism and both chronological and mental age normal controls were compared. The group of individuals who had autism differed from the normal control groups by responding faster to central stimuli than to stimuli left or right of central fixation.[56] Clinicians should be aware of this difference when testing visual fields as well as when the clinician presents items in an individual's peripheral field. To the individual with ASD, an item that suddenly appears in his or her vision may be startling or frightening.

Visual closure

Studies of visual completion or visual closure, which is the ability to integrate visual parts into identifiable wholes, have shown these abilities may be reduced in individuals with ASD. A study comparing a group of children with Pervasive Developmental Disorder (PDD) and a group of non-affected children matched for chronological age and IQ, showed that the ability to visually complete partly occluded shapes and use contextual influences was weaker particularly as the shape complexity increased.[57]

Integration of vision with other senses

Integrating vision with other information such as auditory input can be overwhelming as described by first-hand accounts:

"I have caught myself turning off the car radio while trying to read a road sign."[58]

"To this day, when I speak, I find visual input to be distracting…That's why I usually look somewhere neutral-at the ground or off into the distance-when I'm talking to someone."[59]

This may explain why some autistic individuals look away when trying to listen carefully. Looking away from the speaker serves to reduce the amount of incoming stimuli that the affected individual has to process at one time. Clinicians should be aware that asking the individual to "look at me" may decrease his or her ability to process other types of sensory information simultaneously, such the auditory information in verbal directions. If the clinician is posing a question to the individual with ASD, he or she should allow the person to look away while giving the answer. This decreases the amount of energy required and may facilitate a more thoughtful response. In addition to difficulty in integrating visual information with auditory information, ASD individuals may also have difficulty integrating visual information with proprioceptive, kinesthetic or tactile information.

Differences in processing faces and shifting gaze

The ability to visually process human faces, including emotional expression, is important for normal child development and is linked to social and communicative function.[60] Face processing develops very early in unaffected children occurring in the first year of life.[61,62] The ability to process faces is experience dependent and requires intact function of the right hemisphere.[63] Individuals with ASD have been shown to differ in their processing of faces and emotion expression in behavioral and neuroimaging studies.[64] These differences may be present as early as age six months.[65] ASD individuals can discriminate between the faces of two individuals, but lack other abilities that allow processing of faces to adapt to certain situations or to function at a more refined level.[66]

Analysis of visual scan paths of adult autistic individuals has revealed that they may view the core areas of the face for displaying emotional expression (eyes, nose and mouth) less frequently than they view other areas of the face.[67,68] In making judgments of the emotional state of another person's face, individuals who have ASD were less likely to use information gathered from the eye region and more likely to use information gathered from the mouth.[69,70] Individuals with ASD required more time to process pictures of facial expressions than to process pictures of objects.[71]

This impairment in face processing is thought to be the combined result of innate central nervous system irregularities and the subsequent decreased opportunity to decipher faces.[64] Research studies suggest that differences in face processing abilities in autistic individuals are caused by brain-based deficits in visual perceptual processing rather than caused by social deficits.[72] Studies using functional MRIs suggest these face processing deficits in identifying faces may be located in the extrastriate cortex located in the lateral side of the mid-fusiform gyrus, a brain region also known as the fusiform face area.[73]

Another visual processing difference in ASD individuals that impacts their ability to function socially are differences in gaze shifts. Babies typically react to a shift in gaze that their caretaker makes to note a new target of interest. For example, if the caretaker is looking for a bottle and looks from the refrigerator to the kitchen table, normally developing babies follow this change in the direction of looking to determine what is happening. By age three months, infants respond differently to objects based upon how a viewed caretaker reacts to an object through the adult's emotional facial expression. Awareness of gaze shift is an important precursor for shared or joint attention between the caretaker and child and serves as a basis for social and emotional development. Individuals with autism make significantly fewer shifts in gaze by age 14 months.[74] Those with ASD also have difficulty linking another person's eye gaze with intent, e.g. they cannot use the cue of where another person is looking as an indicator of where the other person's interest is directed.[75]

Differences in motion processing

Individuals with autism have been shown to have intact or superior performance on some static visual tasks, such as visual search for an embedded figure and the Block Design Subtest of the Wechsler IQ Test.[76-79] They do, however, have deficits on tasks requiring dynamic vision processing including motion perception. These deficits in visual processing are severe when the associated neural network is complex, therefore requiring greater integration and connectivity. For example, one experiment showed that the orientation of texture-defined gratings was more poorly identified than simple gratings.[80] These deficits vary among individuals in the ASD population. Children with ASD showed a significant form-coherence deficit and a significant motion-coherence deficit, while the performance of the children with Aspergers syndrome did not differ significantly from that of controls on either task.[81]

Visual symptoms used in the screening and diagnosis of ASD

Visual symptoms that are intimately associated with ASD are used in screening and diagnostic testing for the condition include peering at an object while tilting head and looking out of the corner of the eyes; rapid, voluntary, repetitious movement of the fingers and hands, often within the line of the subject's vision; unusual sensory interests, and peering at or looking at things for long periods of time. Another visual behavior include a markedly increased interest in the parts of objects instead of the object as a whole.[82] Other stereotypical behaviors consist of fixating on light patterns, windows or blinds or repetitively lining up toys and objects.[41] Observers of individuals with ASD who display these behaviors sometimes state that the individual with ASD is stimming. Stimming is a lay term that is short for *self-stimulation*. It refers to repetitive body movements or actions that do not appear to be purposeful to the observer. In reality, these behaviors are probably attempts by the individual to regulate an overly stimulated nervous system.

Other visual symptoms used to screen for ASD include poor eye contact, fidgets with objects repetitively, and maintains interest in spinning objects for periods greater than a couple of minutes, as well as does not follow where someone else is looking, walks on tiptoe and stares in space with no apparent purpose and excessive interest in a single toy.[83-85] These symptoms are so strongly associated with autism that they often manifest before the individual even has a diagnosis of autism. In these cases, the parent may be seeking care for a perceived eye problem, unaware that his or her child may an ASD.[86] It is important that optometrists identify and understand these symptoms, so that they can refer undiagnosed individuals for further testing and explain to caretakers and others the biological basis of these differences in vision processing.

Gaze aversion

Gaze aversion is a visual behavior noted in autism in which the individual looks away or avoids eye contact. Although gaze aversion occurs in non-affected developing babies when they are over-stimulated or tired; gaze aversion is more severe and persists longer in individuals with ASD.[87] Studies of children with autism and children matched for age have shown that autistic children when shown facial stimuli with straight eye gaze (full eye contact) on a computer had higher measures of physiological arousal as measured by skin conduction.[88] Some have concluded that gaze aversion is then a behavior to decrease the individual's anxiety or level of arousal. As discussed in the section on face processing abilities, decreased ability to visually process faces may then contribute to gaze aversion as a compensatory action. Poor eye tracking and fixation skills may contribute to gaze aversion as well.[89] Eye tracking studies of the performance of individuals with autism have implicated the fronto-striatal and cerebellar circuitry that control eye movements.[90]

Lateral vision

Another symptom associated with ASD is the persistent attempt to look off to the side of an object of interest, by turning the head while looking out of the corner of the eye. This is also called lateral vision. (See Figure 1). Lateral vision has been attributed to faulty binocular processing and poor inter-hemispheric integration.[91] The anatomy of the visual system results in images from peripheral visual fields (i.e. the far left or right) represented in both hemispheres. When the individual looks out of the corner of his or her eye using their peripheral vision, intact functioning of only one or the other hemisphere is required. To combine binocular images while focusing directly ahead, one needs to have both hemispheres connected. In one research study that investigated inter-hemispheric information transfer in children with and without ASD, the investigators found that children with ASD had a longer reaction time when asked to point to objects presented to both the right and left visual fields simultaneously.[92] For individuals with ASD who have inter-hemispheric integration problems, lateral vision may be a compensatory attempt to study an image while only relying on the function of one hemisphere of the brain and therefore complete the task faster and with less effort. Another explanation for lateral vision is that it occurs as a compensatory action to certain types of visual stimuli. That is, lateral vision is an attempt to regulate visual information by filtering high spatial frequency information (detail), as well as, high temporal frequency information (movement), so that visual information can be processed with minimal discomfort and confusion.[82] This implies that lateral vision is a behavior in which the individual attempts to use peripheral visual processing in place of central vision.

Figure 1: *Lateral vision*

Hand flapping and finger flicking

The voluntary, repetitious movement of the fingers and hands, often within the line of the subject's vision is another symptom closely linked to ASD. (See Figure 2). The behaviors of hand flapping or flicking fingers near the face have been explained as compensations for poor visuo-spatial skills. These individuals lack the visuo-spatial abilities to know where their body parts are or where their bodies are in relationship to other objects. As a result, individuals with ASD compensate by seeking additional sensory input to tell them where they are in space. [44]

Treatment of visual symptoms found in individuals with ASD

For the clinician seeking to treat the visual problems of individuals with ASD, important questions remain. To what extent are visual symptoms treatable, particularly those visual symptoms, such as gaze aversion and lateral gaze that are very much associated with the condition? What interventions are most effective and for which individuals diagnosed with ASD? There is some evidence to support optometric intervention. Kaplan and his colleagues have documented changes in posture, body orientation and visual motor task performance using yoked prism through a series of research studies[49,50,93] Other clinicians have published case reports that reported positive improvements in posture and balance, behavior and language when using yoked prism, as well as improved spatial awareness and visual motor skills using optometric vision therapy[10,46,52] Schulman reviewed the outcome of 20 patients treated with OVT in her practice. In considering treatment outcomes described as improved visual self-stimulation behaviors, visual

Figure 2: *Finger flicking*

awareness, visual skills and observed socialization and communication in her practice, she concluded that 25 percent made slow progress, 30 percent, made fair progress and 45 percent made very good progress.[18]

Many non-optometric interventions for individuals with autism including Applied Behavior Analysis, DIR, and Relationship Developmental Intervention (RDI), incorporate some objectives that aim to improve eye contact and decrease self-stimulation behaviors including those that are related to vision.[91,94,95] It is difficult to report how successful these interventions are at addressing visual problems since success is measured globally using standardized testing instruments that assess the severity of the individual's autism. In these tests, visual behaviors, as measured directly, are only small components of areas assessed that often include an assessment of communication, play skills, social abilities and adaptive behavior.

Conclusion

Visual symptoms found in individuals with ASD are pervasive, multi-modal and often severe in their intensity. These symptoms are biologically based and are linked to physiological differences in processing visual and other sensory information. Some symptoms may be linked to difficulties due to problems in refractive error, binocularity, ocular motility, and contrast sensitivity processing. Within the ASD population, the most severe symptoms are due to difficulties in visual processing. The concept of Individual-Differences from the DIR model may explain variation of these symptoms between different individuals with ASD. Visual differences include hyper- and hypo-sensitivity, photosensitivity, color perception, processing central, visuo-spatial and visual-motor processing and spatial awareness, visual neglect and a multitude of other deficit areas.

Various symptomatologies associated with ASD including gaze aversion, lateral vision and hand flapping are frequently used to screen for and diagnose this condition. To the inexperienced person, these symptoms may appear to be so strange or bizarre, that the individual who displays them may be perceived as less than human. It is important to not lose sight of the fact that the behaviors are the result of or compensations for biological differences in *very* human individuals. Clinical observation of symptoms is especially important when individuals are not able to articulate the symptoms they are experiencing or not able to respond to formal testing.[96] Understanding the link between visual symptoms and their underlying visual differences is important so that the health care professional who cares for patients with ASD can accurately gather information, complete diagnostic testing, interpret results, choose effective treatments, educate the patient and his or her caregivers and make appropriate referrals when necessary.

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