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VISUAL PROCESSING AND PERCEPTION DEFICITS IN MULTIPLE SCLEROSIS PATIENTS: REVIEW

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Abstract

Multiple sclerosis (MS) is a chronic immune-mediated demyelinating encephalopathy disorder that is likely to impair visual functioning. Although cognitive problems in MS, especially memory and processing speed deficiency, have been well-established, there is relatively little attention given to visual perceptual dysfunction. The new data show that visual impairment in MS is not limited to optic neuritis and includes the disruptions at the different levels of the visual processing hierarchy, which are both cortical and subcortical systems. The synthesis of the results of behavioral, neuropsychological, neuroimaging, and socioemotional studies investigating visual processing and perceptual deficits in MS patients shows that the psychophysical testing, neuropsychological

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tests, and functional and structural neuroimaging indicate the presence of visual discrimination, visuospatial perception, visual processing speed, and emotion recognition impairments. These deficits are observed partially regardless of the optic neuritis history and duration of the disease. Taken together, the literature implies that visual perceptual impairment in MS is a combination of decelerated neuronal conduction, restructured functional connections, and restructured network formation. Although it is a clinically relevant area, visual perception is still poorly evaluated in the standard MS care. A more intensive perceptual measure combination could enhance the diagnostic sensitivity and guide specific rehabilitation interventions.

INTRODUCTION

About 2.9 million people worldwide suffer from multiple sclerosis, a persistent, immune-mediated, demyelinating condition of the central nervous system (Feen et al., 2022). It mainly affects myelinated axons in both white and gray matter, which causes neuroinflammation, demyelination, and neurodegeneration (Ayadi et al., 2022). Although the disorder is typically linked to motor, sensory, and coordination impairments, visual impairment is among the most frequent and earliest presentations, impacting up to 80% of patients throughout the course of the illness historically (Tong et al., 2025). Though optic neuritis has been the main cause of visual impairment in MS, current research reveals that visual processing and perception abnormalities go much beyond ON episodes, therefore implicating cortical and subcortical visual pathways in the more general pathophysiology of MS (Backner et al., 2022). Historically, multiple sclerosis clinical trials have lacked sensitive, vision-specific outcome measures. Low-contrast letter acuity (LCLA) has emerged as the leading candidate to measure visual impairment in multiple sclerosis.

From retinal encoding and optic-nerve transmission to cortical integration and higher-order visual perception, visual processing is the hierarchical transformation of visual input (Cessac, 2022). Anywhere along this pathway, damage might change the interpretation and perception of visual data. Demolition and axonal loss in MS affect both afferent and efferent components of vision, which

slows visual processing speed, lowers contrast sensitivity, causes depth perception errors, and messes up visuospatial organization Patients lacking a known medical history of ON may exhibit extended latencies or lower visual-evoked potential amplitudes, which point to subclinical involvement of the visual pathway (Vecchio et al., 2023).

Recent research using functional MRI and diffusion tensor imaging reveals that the optic radiations, lateral geniculate nucleus, and occipital cortex exhibit altered activation patterns and reduced integrity, therefore implying that visual perceptual difficulties in MS go beyond just remembering what things look like, knowing what they are, and knowing their location in space (Vagias et al., 2024). These results imply that MS-related damage impacts not just the first sensory phases of visual processing but also cortical systems supporting visual attention and perception (Dam et al., 2024). Visual processing speed measured with tests such as the Symbol Digit Modalities Test (SDMT) has been shown to be the most often affected cognitive domain in MS; it strongly reflects visual cortical atrophy and microstructural deterioration (Chylińska et al., 2023).

Clinically, problems with visual perception and processing greatly impair a person's capacity for good performance. Poor motion and depth perception can affect driving safety, reading speed, and spatial navigation in MS patients (Suh et al., 2024; Zai et al., n.d.). In MS patients, a lower quality of life and a greater risk of falls have been related to poorer visual discrimination and reduced contrast sensitivity (Onoja et al., 2023). Furthermore, as many cognitive tests are visually mediated, undiscovered visual perceptual deficits can affect neuropsychological evaluations and cause underestimation or misinterpretation of cognitive impairment (Vagias et al., 2024).

Despite rising awareness of these issues, routine MS treatment still falls short in checking for perceptual and visual processing impairments. Most clinical examinations focus on retinal morphology using optical coherence tomography (OCT) and visual acuity; visual cognitive integration and perceptual accuracy are rarely extensively studied (Dreyer-Alster, Gal, and Achiron 2022). According to recent integrative studies, a multisystem visual model in MS consists of connected but independent components, including afferent visual input, efferent oculomotor control, and cortical perceptual processing, as contributing to visual impairment (Vagias et al., 2024).

According to this model, clearly defining visual perception is important not just as a symptom domain but also as a possible biomarker of cortical network integrity and disease development (Mey & Desilva, 2023).

However, particularly in those without evident ON or significant impairment, there are still significant gaps in our knowledge of the exact kind and severity of visual perceptual impairments in MS. It is unclear if visual impairments reflect independent cortical abnormalities, a downstream effect of slowed visual conduction, or a mix of both (Backner et al., 2022). Furthermore, task design differences and a lack of agreed-upon assessment techniques hinder clinical translation and cross-study comparison (Inojosa C. et al., 2020).

Therefore, the current study aims to investigate visual processing and perceptual abnormalities in individuals with Multiple Sclerosis, with a focus on both low-level sensory and high-level cognitive aspects of vision. This study aims to identify how visual-perceptual abnormalities manifest and relate to illness duration and functional status by evaluating visual discrimination, contrast sensitivity, and visuospatial awareness. Knowing these patterns could help us to see early diagnostic indicators and possible rehabilitation goals aimed at preserving visual and cognitive abilities in MS.

Methodology:

The review was performed as a narrative literature review by the agreement to synthesize the existing evidence on the topic of visual processing and perceptual impairments among patients with multiple sclerosis (MS). It was concerned with the combination of behavioral, neuropsychological, electrophysiological, neuroimaging, and socioemotional research results to give a complete picture of the impairment at various levels of the visual processing hierarchy.

The literature search was organized with the help of electronic databases (PubMed, Scopus, Web of Science, and Google Scholar). The search strategy used to conduct the research contained the key word combinations in MS and visual functioning, such as multiple sclerosis, visual processing, visual perception, visuospatial functioning, contrast sensitivity, optic neuritis, visual evoked potentials, functional magnetic resonance imaging and diffusion tensor imaging. Moreover, the reference lists

of the appropriate reviews and key studies were screened manually in order to find more relevant publications.

The inclusion criteria were that: The studies have to include patients with MS and need to measure visual processing or perceptual functions through behavioral testing, neuropsychological analysis, electrophysiological, or structural and functional neuroimaging. Both cross-sectional and longitudinal studies were enclosed, whereas studies that were restricted to isolated ocular pathology, animal research, case reports, and publications in non-English were prevented. The results were synthesized qualitatively and put them together thematically based on the degrees of visual processing, which can enable the integrated assessment of the mechanisms, clinical implications, and functional implications of visual perceptual deficiency in MS.

MS-Related Disruption and Visual Processing Hierarchy.

The mechanism of visual processing is considered to be hierarchical as it involves the primary acceptance of sensory codes, middle perception structuring, and the interpretation of higher cognitive research. Preliminarily, there is activation and transmission of retinal photoreceptors to the subcortical and cortical visual regions via the optic nerve. Visual information is later incorporated with the attentional system, memory, and executive systems to facilitate perception and behavior (Lopes Costa et al., 2016).

In MS, neural signaling at this level is interrupted by inflammatory demyelination and neurodegeneration. Lesions to primary visual pathways cause conduction and signal fidelity slowing, and cortical lesions and disconnection of the networks disrupt visual information integration and decoding. Consequently, visual perceptual losses in MS indicate local sensory and distributed network-based failures.

Multiple Sclerosis: Low-Level Visual Processing Deficits.

It is always shown that MS patients have deficiencies in the low-level visual processing, regardless of whether visual acuity seems intact. One of the most common deficits that is commonly reported is

reduced contrast sensitivity, which indicates early recruitment of magnocellular pathways. The temporal processing disorders, such as slowness in visual responses, are other signs that show slowing of neural conduction.

The results of visual-evoked potential show long latencies and low amplitudes, which are in accordance with the slowing of conduction due to demyelination. Notably, these abnormalities are commonly found in patients who have no clinical history of optic neuritis, demonstrating that there is subclinical involvement of the visual pathways (Sakai, Feller, Galetta, Galetta, & Balcer, 2011). The results highlight the weakness of using visual acuity measures to evaluate visual functioning in MS.

Loss of depth perception and motion processing is also frequently reported and leads to functional impairment in day-to-day activities. The combination of these impairments shows that early visual dysfunction of the senses is a main characteristic of the MS-related pathology.

Medium and Advanced Visual Perception

Intermediate and High-Level Visual Perception

Form Perception and Visual Discrimination.

The neuropsychological research that uses tasks including the Hooper Visual Organization Test and the Visual Form Discrimination test shows that MS patients are challenged by visual organization and perceptual discrimination. The choice of these tools is usually informed by the fact that they reduce motor and general cognitive confounds, and, therefore, any observed impairments are predictors of true perceptual impairment, and not secondary to the impact of physical disability (Gontkovsky, 2023).

The patterns of performance in these measures indicate that different tests have different variables of visual-spatial perception. This diversity underscores the complex nature of visual perceptual impairment of MS and the necessity of holistic methods of assessment.

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The Postural-Spatial Visuospatial Memory and Organization.

Visuospatial learning and delayed recall deficit are always reported in MS populations, especially when the tasks involve the Brief Visuospatial Memory Test-Revised. Such impairments are usually not global, but domain-specific since naming and general intelligence are not usually affected (Macias Islas & Ciampi, 2019). These results suggest that there is a selective vulnerability of visuospatial memory systems, which is probably the dorsal visual stream dysfunction.

Deficits in visuospatial memory are regarded as sensitive measures of neural impairment that are caused by MS and have been linked to changes in cortical and subcortical architectures due to the disease.

Visual Processing Speed

One of the most common impaired cognitive areas in MS is the speed of visual processing, which is often evaluated with the help of the Symbol Digit Modalities Test. Display of this task has been associated with the atrophy of the visual cortex and microstructural decay. Nonetheless, since the test involves motor responses, attention, and working memory, it is not specific as a pure measure of visual processing speed. This is to emphasize the role of complementing processing speed measures with perceptual-specific measures (Benedict et al., 2017).

Correlates of Neuroimaging of Visual Perceptual Deficits.

Neuroimaging structural studies show that the optic radiations, lateral geniculate nucleus, and occipital cortex are less intact in MS, and diffusion tensor imaging indicates microstructural damage, which is associated with the loss of speed of visual processing and accurate perceptions.

The functional neuroimaging research also indicates the changes in patterns of activation and connectivity in visual, attentional, and default mode networks. Heightened default mode network connectivity to visual mode networks has been considered as compensatory and inefficient restructuring. The decreased connection between frontal eye fields and parietal areas coincides with

the behavioral data on the impaired visuospatial attention and processing speed (Pumphrey et al., 2024).

Altogether, the neuroimaging results indicate that visual perceptual impairments in MS are due to structural disconnection as well as maladaptive functional network dynamics.

Socioemotional and Multimodal Visual Perception.

In addition to the conventional visual perception, MS also influences socioemotional processing. The investigations of facial emotion recognition show that people with MS have less accuracy than healthy individuals, and the outcomes vary with age and disease status. The multimodal emotion processing, the processes that involve a combination of facial expression and vocal cues, seems to be more strongly associated with the overall level of cognitive severity than with emotional awareness. Interestingly, although there are self-reported decreases in socioemotional sensitivity, a report by informants does not tend to support such changes as subtle deficits or compensation processes. These results suggest that the interactions between perceptions and cognition in MS do not lie within the scope of the visual domain only but refer to more generalized integrative mechanisms (Behnia et al., 2025).

Clinical Implications

Deficits in visual perception in MS are of importance in terms of diagnosis and functionality. Depending on visual ability and retinal imaging does not help in the detection of higher-order perceptual dysfunction. As a result, the visual impairments might go unnoticed and persist in disrupting the operations and cognitive evaluation of the day-to-day activities.

Neuropsychological tests that fail to consider visual perceptual impairments are likely to result in the misinterpretation of poor performance as a manifestation of generalized cognitive decline. The addition of perceptual test measures to a typical clinical setting could enhance the accuracy of diagnosis and specially planned programs of rehabilitation (Macias Islas & Ciampi, 2019).

Present shortcomings and future perspectives.

In spite of the increasing evidence, there are a number of gaps in the literature. Standardized, clinically viable visual perceptual assessment batteries of MS do not exist, and longitudinal studies of the dynamics of perceptual impairment are rare. The connection between the compensatory neural processes and functional result is still insufficiently studied, and there is an underutilization of ecologically valid visual tasks. Future studies need to combine methods of behavioral and neuroimaging, consider various types of MS, and assess specific visual-cognitive rehabilitation interventions.

Conclusion

In multiple sclerosis, visual processing and perceptual impairment are beyond the optic nerve pathology and depend on distributed cortical and subcortical networks. Behavioral, neuropsychological, and neuroimaging evidence depict a variety of levels of visual hierarchy impairment, and major functional and clinical implications. The identification of visual perception as a specific and clinically significant area in MS can lead to a greater level of early detection, an increase in the accuracy of cognitive assessment, and the development of a specific intervention approach.

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