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# Types and Clinical Associations of Suppression

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## ABSTRACT

Suppression is a neural adaptation that inhibits conflicting visual input from one eye to avoid diplopia or visual confusion, particularly in the presence of strabismus, amblyopia, or anisometropia. Although beneficial as a compensatory mechanism, persistent suppression can disrupt binocular integration, leading to long-term sensory deficits. This systematic review aims to classify the types of suppression, examine their clinical associations with various binocular vision disorders, evaluate diagnostic approaches, and assess available therapeutic interventions. A systematic search was conducted across PubMed, Scopus, Web of Science, Cochrane Library, and Google Scholar, covering articles published from January 2000 to May 2025. After removing duplicates and applying inclusion criteria, 38 studies were included. Data were extracted and quality assessed using the Cochrane Risk of Bias tool, Newcastle-Ottawa Scale, and JBI appraisal checklists. Suppression was categorized into facultative, obligatory, central, and peripheral types, each associated with specific clinical conditions. Strabismus—particularly esotropia and exotropia—was the most common association, followed by amblyopia, anisometropia, and convergence insufficiency. Diagnostic tools such as the Worth 4-dot test, Bagolini lenses, and cover testing varied in sensitivity and application. Management options including occlusion therapy, vision therapy, and prisms showed moderate to strong effectiveness, particularly when initiated early. Understanding suppression types and their clinical contexts is essential for accurate diagnosis and tailored intervention. Future research should focus on standardizing assessment tools and expanding evidence on adult neuroplasticity in suppression therapy.

## INTRODUCTION

### Background and Significance of Suppression in Clinical Practice

Suppression is a neuro-adaptive mechanism that allows the visual system to eliminate the perception of diplopia or visual confusion resulting from dissimilar images received by each eye, especially in the presence of ocular misalignment or sensory imbalance. It is primarily associated with conditions such as strabismus, amblyopia, anisometropia, and binocular vision anomalies [1,2]. Suppression may serve a protective function, enabling the individual to maintain comfortable vision by disregarding conflicting visual input. However, this adaptation can interfere with binocular fusion, stereopsis, and depth perception, especially if left untreated during the critical period of visual development [3]. Clinically, suppression complicates the diagnosis and management of binocular vision disorders. It often masks underlying anomalies, delays treatment, and can limit the success of therapies such as strabismus surgery or amblyopia rehabilitation [4]. Understanding the types and characteristics of suppression is vital for customizing treatment and predicting visual prognosis. It also informs the design of therapeutic interventions aimed at restoring binocular function and cortical plasticity.

**Research Question and Objectives**

Given the clinical relevance of suppression in various binocular vision disorders, this systematic review seeks to address the following research question:

"What are the types and clinical associations of suppression, and how do they impact diagnosis and treatment in binocular vision disorders?"

1. Classify and describe the various types of suppression reported in clinical literature.
2. Identify the clinical conditions most commonly associated with suppression.
3. Evaluate the diagnostic methods used to detect and quantify suppression.
4. Assess the effectiveness of therapeutic interventions targeted at managing suppression.
5. Highlight gaps in existing literature and suggest directions for future research.

## METHODS

**Search Strategy and Databases Searched**

A comprehensive literature search was conducted to identify relevant studies examining the types, clinical associations, diagnostic techniques, and management of suppression in binocular vision disorders. Electronic databases searched included PubMed, Scopus, Web of Science, Google Scholar, and the Cochrane Library, in accordance with the PRISMA 2020 guidelines [5]. Search terms were developed using Medical Subject Headings (MeSH) and keyword combinations, including: “visual suppression,” “binocular vision disorders,” “strabismus suppression,” “amblyopia and suppression,” “facultative suppression,” “central suppression,” “Worth 4-dot,” “Bagolini lenses,” and “vision therapy for suppression.” Boolean operators (AND, OR) were applied to optimize search sensitivity and specificity. The search was limited to peer-reviewed articles published in English between January 2000 and May 2025 to ensure relevance and recency of evidence [6].

**Study Selection and Screening Process**

A total of 1,284 articles were identified through the database search. After the removal of 322 duplicates, 962 unique articles were screened by title and abstract. Based on predefined eligibility criteria, 146 full-text articles were reviewed for inclusion. Following full-text assessment, 38 studies met all inclusion criteria and were selected for final analysis.

**The inclusion criteria were as follows:**

- Original studies involving human participants
- Focused on suppression in relation to binocular vision conditions
- Articles describing types, diagnosis, or management of suppression
- Availability of full text in English

**Exclusion criteria included:**

- Non-English language publications
- Conference abstracts, case reports, editorials, or narrative reviews
- Animal studies or studies on unrelated ocular diseases

The screening and selection process was conducted independently by two reviewers. Any disagreements were resolved by consensus or by involving a third reviewer. The entire selection process followed the PRISMA 2020 framework and is illustrated in a PRISMA flow diagram [5].

**Data Extraction and Quality Assessment**

A standardized data extraction sheet was used to collect the following information from each included study:

- Authors and year of publication
- Study design and sample size
- Participant characteristics
- Type of suppression described
- Diagnostic tests and therapeutic approaches used
- Major outcomes and conclusions

The quality of the included studies was appraised using the following tools:

- Cochrane Risk of Bias Tool 2.0 for randomized controlled trials
- Newcastle-Ottawa Scale (NOS) for cohort and case-control studies [7]
- JBI Critical Appraisal Checklists for cross-sectional and descriptive studies [8]

Additionally, the Oxford Centre for Evidence-Based Medicine (OCEBM) 2009 levels of evidence were applied to classify the strength of the evidence presented in each study [9].

**Types of Suppression**

**Classification and Description of Different Types of Suppression**

Suppression in binocular vision disorders is not a uniform phenomenon. It varies based on conditions of viewing, neural involvement, extent of the retinal area affected, and duration. Several classification systems exist, but broadly, suppression can be divided into facultative vs. obligatory and central vs. peripheral types. Understanding these types is essential for diagnosing and managing disorders such as strabismus, amblyopia, and convergence insufficiency.

**Facultative Suppression**

Facultative suppression refers to the temporary inhibition of visual input from one eye, typically occurring only during binocular viewing conditions. It is a sensory adaptation that arises to avoid diplopia (double vision) or visual confusion when the eyes are misaligned. Notably, this type of suppression is absent when the individual views monocularly [10]. Facultative suppression is commonly seen in intermittent strabismus or phorias, where the visual system suppresses the deviating eye only under specific conditions [11]. This type of suppression is usually shallow and reversible, especially in patients with recent-onset or intermittent strabismus. It often responds well to vision therapy, orthoptic exercises, or surgical correction, as the visual cortex has not fully adapted to constant misalignment [12].

**Obligatory Suppression**

In contrast, obligatory suppression is a more entrenched and persistent phenomenon. It occurs constantly, regardless of whether the visual input is monocular or binocular. This type of suppression typically develops in long-standing cases of strabismus or severe amblyopia and reflects deep sensory adaptation by the brain to prevent persistent diplopia [13]. Obligatory suppression is often associated with early-onset esotropia, where the visual system suppresses the image from the deviating eye to maintain a stable perception. The suppression scotoma (the area of visual field being suppressed) is typically large and may encompass both foveal and peripheral regions, making therapeutic intervention more challenging [14]. Because it is persistent and deep, obligatory suppression is more resistant to conventional treatments and may require prolonged vision therapy or prism adaptation therapy.

**Central Suppression**

Central suppression refers specifically to the inhibition of visual information at or near the fovea of the suppressed eye. This is a hallmark of amblyopia and strabismus where central retinal correspondence is disrupted. The suppression affects central vision and contributes to the lack of stereopsis and visual acuity reduction in the affected eye [15]. In clinical testing, central suppression is often detected using techniques such as the Worth 4-dot test or Bagolini striated lenses, where the central portion of the visual field is suppressed during fusion attempts. Because it impairs detailed vision, central suppression is a significant concern in academic and occupational performance, particularly in children with amblyopia [16]. The depth of central suppression correlates strongly with the severity of amblyopia and is often used as a therapeutic indicator. Studies have shown that reduction in central suppression is associated with improvements in visual acuity and binocular function following vision therapy or occlusion therapy [17].

**Peripheral Suppression**

Peripheral suppression affects the peripheral retina, typically beyond the macular or foveal region. This type is more commonly associated with individuals who have large-angle strabismus, where the peripheral image from the deviating eye is suppressed to avoid confusion with the fixating eye's visual field [18]. Unlike central suppression, peripheral suppression may not significantly impact acuity but can impair peripheral fusion and depth perception. It is often less problematic in everyday visual tasks but may hinder spatial orientation and coordination. Peripheral suppression is typically detected using large field tests such as synoptophore assessments or wide-field stereopsis tests.

Peripheral suppression can coexist with central suppression in severe or long-standing binocular anomalies, forming a comprehensive suppression scotoma that covers both foveal and peripheral retinal areas. This can severely reduce the binocular visual field and functional performance [19].

Prevalence and Characteristics of Each Type

The prevalence of suppression types depends significantly on the underlying ocular condition and the age of onset. For instance, facultative suppression is more common in patients with intermittent exotropia and can be found in up to 40-60% of such individuals [20]. Obligatory suppression is prevalent in early-onset esotropia and amblyopia, often affecting more than 70% of those with constant strabismus from early childhood [13].

Central suppression is almost universally present in moderate to severe amblyopia and is observed in more than 85% of pediatric amblyopic cases [16]. Peripheral suppression, although less frequently discussed, has been reported in individuals with large-angle deviations, affecting both horizontal and vertical peripheral fields [18].

Overall, the characteristics of suppression vary with patient age, duration of the binocular anomaly, and whether the anomaly is intermittent or constant. Early diagnosis and classification are key to guiding effective treatment strategies.

**Clinical Associations of Suppression**

Suppression plays a central role in the pathophysiology and clinical manifestation of several binocular vision disorders. It often serves as a compensatory mechanism to avoid diplopia or visual confusion in the presence of disrupted binocular alignment or unequal visual input. Its presence, depth, and type vary across ocular conditions and influence treatment planning and prognosis. Below is a synthesis of suppression's associations with key clinical conditions.

**Strabismus (e.g., Esotropia, Exotropia)**

Suppression is one of the most prominent sensory adaptations in patients with strabismus, particularly in early-onset or constant cases. It is strongly associated with both esotropia and exotropia, although the patterns and prevalence differ.

In esotropia, especially congenital or infantile-onset esotropia, suppression tends to be central and obligatory, involving the fovea and a large central scotoma in the deviating eye. This helps the individual avoid diplopia but hinders binocular fusion development and stereopsis [10]. The suppression zone often corresponds to the angle of deviation and tends to be deeper and more resistant to treatment than in exotropia [14].

In contrast, intermittent exotropia is more often associated with facultative suppression. The brain suppresses input from the deviating eye only during periods of misalignment. Suppression in exotropia is usually peripheral, sparing the central retina, allowing patients to maintain good visual acuity and stereopsis during alignment phases [20]. This makes intermittent exotropia more amenable to non-surgical interventions such as orthoptics or vergence therapy.

Research consistently shows a high prevalence of suppression in strabismic patients, with some studies reporting rates as high as 80-90%, particularly in constant strabismus [18]. The depth and extent of suppression are predictive of visual outcomes following strabismus surgery [21].

Amblyopia

Suppression is integral to the development and persistence of amblyopia, especially in strabismic amblyopia and anisometropic amblyopia. In amblyopia, suppression is typically central and obligatory, affecting foveal vision in the amblyopic eye. It represents a long-standing cortical adaptation that inhibits visual input to avoid perceptual competition between the dominant and amblyopic eye [30].

The presence of deep central suppression prevents binocular integration and contributes to the poor acuity and lack of stereopsis characteristic of amblyopia. It has been shown that the magnitude of suppression is more closely related to binocular dysfunction than the visual acuity deficit itself [31]. In fact, suppression has been identified as a barrier to successful amblyopia treatment and is now considered a therapeutic target in novel binocular therapies [32].

Recent evidence supports the idea that reducing suppression through dichoptic training or perceptual learning can improve binocular function and even visual acuity in adults, challenging the notion that amblyopia is irreversible beyond a critical period [33].

**Anisometropia**

Anisometropic suppression occurs when significant refractive differences between the two eyes lead to chronic blurred input from one eye. This visual discrepancy results in the suppression of the defocused image to maintain comfortable binocular vision [34]. While not always resulting in amblyopia, chronic anisometropic suppression may progress to amblyopia if not managed early, particularly in pediatric populations.

Suppression in anisometropia is usually central and may be facultative or obligatory, depending on the duration and magnitude of refractive imbalance. Early correction with spectacles or contact lenses, often combined with occlusion therapy, can reduce the risk of long-term suppression and amblyopia [22].

**Binocular Vision Disorders (e.g., Convergence Insufficiency)**

Although classically associated with strabismus and amblyopia, suppression also occurs in non-strabismic binocular vision disorders, particularly in convergence insufficiency (CI). CI patients may exhibit intermittent suppression of one eye, especially during near tasks, to reduce the discomfort of diplopia or blurred vision [24]. The suppression in CI is often facultative and shallow, predominantly affecting near vision tasks such as reading. It is reversible and tends to improve significantly with vergence therapy. Clinical studies have demonstrated that suppression is an important contributor to symptoms in CI and may serve as an objective measure of treatment efficacy [35].

Similarly, patients with decompensated phorias, accommodative disorders, or vertical imbalances may show intermittent suppression, which impairs binocular comfort and performance. Addressing this suppression through appropriate prism correction, vision therapy, or accommodative training can restore binocular function and relieve symptoms.

**Strength of Evidence and Consistency of Findings**

The association between suppression and clinical conditions such as strabismus, amblyopia, and anisometropia is well-documented and supported by high-quality evidence, including randomized controlled trials, observational studies, and neurophysiological investigations [31,34]. The consistency of findings across diverse populations and diagnostic methods enhances the reliability of these associations.

However, evidence on suppression in non-strabismic binocular vision disorders is relatively limited, with fewer large-scale or longitudinal studies. Nonetheless, clinical reports and small controlled trials have consistently demonstrated suppression in CI and other binocular anomalies, suggesting a valid, though less-explored, association [24,35].

The evidence supports a strong and consistent link between suppression and various visual disorders, with implications for diagnosis, prognosis, and treatment outcomes.

**Diagnostic Techniques**

The diagnosis and quantification of suppression are critical for the evaluation and management of binocular vision disorders. Various clinical and laboratory-based tools are employed to assess the presence, type, depth, and extent of suppression. Each method differs in sensitivity, reliability, and clinical utility. Accurate diagnosis helps guide appropriate therapeutic interventions, monitor treatment progress, and predict visual outcomes.

**Cover Testing**

The cover test is a fundamental method in binocular vision assessment and is used primarily to detect ocular misalignment rather than suppression itself. However, it provides indirect evidence of suppression. During the cover-uncover test, if there is no refixation movement of the non-fixating eye, it may suggest the presence of suppression in that eye [1]. The alternate cover test can help estimate the magnitude of a phoria or tropia, and absence of diplopia or awareness during the test suggests sensory suppression.

While the cover test is simple and widely used, its sensitivity to shallow or intermittent suppression is limited, and it does not localize the suppression zone. However, it is useful for detecting associated deviations and monitoring changes over time during therapy [22].

Worth 4-Dot Test

The Worth 4-Dot test is one of the most commonly used tools for detecting central vs. peripheral suppression. It uses a red-green filter and a flashlight with four lights: one red, two green, and one white. The patient wears red-green glasses (red over the right eye and green over the left) and reports what they see under both near and distance viewing conditions.

- Seeing four lights indicates normal fusion.
- Seeing two red or three green lights suggests suppression of one eye.
- Seeing five lights suggests diplopia [24].

This test allows clinicians to detect whether suppression is central (at distance) or peripheral (at near) based on the patient's responses. It is easy to administer and interpret. However, it is subjective, and the result depends on the patient's cooperation, attention, and interpretation of visual stimuli. It is more suitable for older children and adults and may not detect very deep or subtle suppression [9].

**Bagolini Striated Lens Test**

The Bagolini striated lens test is another sensitive method for assessing suppression, fusion, and retinal correspondence under near-natural viewing conditions. Patients wear striated lenses over each eye, oriented at opposite angles, while viewing a light source. Each lens produces a streak of light perpendicular to the striations.

- Seeing two intersecting lines (X pattern) suggests normal binocular fusion.
- Seeing one line only indicates suppression of the corresponding eye.
- Seeing two lines not intersecting suggests diplopia or anomalous retinal correspondence [34]

This test is considered more naturalistic and less dissociative than the Worth 4-Dot test, making it useful in detecting shallow or intermittent suppression [24]. However, it requires subjective input, and interpretation may be difficult in young or uncooperative patients.

**Other Diagnostic Tools**

**Synoptophore**

The synoptophore is a traditional instrument used in orthoptic practice for assessing suppression zones, fusion ranges, and anomalous retinal correspondence. It offers precise control over vergence angles and allows for mapping of suppression scotomas using contour fusion slides. It is particularly useful in quantifying suppression size and depth in strabismic patients [29]. However, the device is bulky, expensive, and requires specialized training to administer.

Visuoscopy and Haidinger Brushes

Visuoscopy and Haidinger brush techniques can be used to assess central fixation and suppression in amblyopia. These tools help determine the exact fixation point of the non-dominant eye, which indirectly reflects suppression if eccentric fixation is found [1].

**Stereopsis Tests**

Although stereopsis tests (e.g., Randot, Titmus Fly) do not directly measure suppression, failure to achieve stereopsis in patients with known alignment can suggest the presence of suppression [22]. Some advanced stereoacuity tests now incorporate suppression checks as part of their assessment protocols.

**Dichoptic Presentation and Psychophysical Tests**

More recent advances have introduced computer-based dichoptic tests such as the Binocular Rivalry Test, Contrast Balance Test, and dichoptic letter charts, which can quantitatively assess the depth of suppression. These tools offer greater sensitivity and reliability than traditional methods and are especially useful in research settings and modern amblyopia therapy monitoring [31,32].

**Accuracy and Reliability of Each Technique**

The cover test is reliable for detecting alignment but insensitive to mild suppression. The Worth 4-Dot test offers good utility in routine clinics, especially when performed at both near and distance, but is limited by subjective bias and inability to quantify suppression depth [9].

The Bagolini test is more sensitive to shallow suppression and less dissociative, making it particularly useful in cases of intermittent suppression or fusion difficulties. The synoptophore provides quantitative assessment but is less accessible due to cost and size. Dichoptic psychophysical tests are currently the most sensitive and reliable in measuring the depth and spatial extent of suppression, but they are mainly used in research or specialized clinical settings [30].

In general, no single test is sufficient. A combination of techniques is often required to detect, localize, and quantify suppression effectively across different clinical conditions and age groups.

## Clinical Implications and Management

### Impact of Suppression on Binocular Vision and Visual Function

Suppression has profound implications for binocular vision development, stability, and visual function. It represents a neural strategy for avoiding diplopia and visual confusion in cases of ocular misalignment or unequal visual input. However, this adaptation comes at a cost: reduced stereopsis, diminished depth perception, and disrupted binocular integration [34]. In children, prolonged suppression may interfere with the development of normal binocular vision, leading to amblyopia or permanent sensory deficits [9]. Suppression also affects functional performance, particularly in tasks requiring precise depth judgment such as reading, sports, and occupational activities. In adults, long-standing suppression may hinder recovery even after surgical alignment of the eyes if binocular pathways remain inactive [31]. Moreover, suppression can influence diagnostic interpretation, mask the presence of diplopia, and complicate therapy for binocular vision disorders [22].

### Effectiveness of Treatment Options

The primary goal of treatment is to eliminate or reduce suppression to restore normal binocular function. Several interventions have been studied and applied with varying degrees of success depending on the patient's age, the type and duration of suppression, and the underlying condition.

#### 1. Occlusion Therapy

Occlusion therapy (patching) remains one of the cornerstone treatments for amblyopia, especially in children. By forcing the use of the amblyopic or suppressed eye, it disrupts suppression and stimulates visual development [36].

Numerous clinical trials have validated the efficacy of occlusion in improving visual acuity, with variable success in restoring stereopsis. The Pediatric Eye Disease Investigator Group (PEDIG) found that patching 2–6 hours daily significantly improved visual acuity in children aged 3 to 7 years with amblyopia [37]. However, occlusion does not necessarily restore binocular vision or eliminate suppression in all cases. Suppression may persist even after acuity is restored, especially in cases of longstanding strabismus or deep central suppression.

#### 2. Vision Therapy

Vision therapy, including orthoptic exercises, dichoptic training, and perceptual learning, has gained prominence for treating suppression, particularly in cases resistant to patching. These therapies aim to improve fusional vergence amplitudes, binocular integration, and reduce suppression zones by training both eyes to work together.

Dichoptic therapy presents separate stimuli to each eye with different contrast or luminance levels to promote binocular combination while weakening suppression [38]. Several studies have demonstrated that vision therapy can reduce suppression depth and improve stereopsis and visual acuity in both children and adults [32].

Moreover, computer-based vision therapy programs allow home-based treatment and real-time feedback, making therapy more accessible and engaging. Unlike occlusion, vision therapy directly targets binocular dysfunction and may be more effective in re-establishing fusion and stereopsis [33].

**3. Prism Prescription**

Prisms are frequently prescribed in cases of deviations with associated suppression, particularly when fusion potential exists. By aligning images from both eyes onto corresponding retinal points, prisms reduce the demand on fusional vergence and promote binocular viewing [22].

Fresnel prisms are often used in early intervention or diagnostic settings to measure suppression and predict outcomes of alignment procedures. When suppression is facultative or shallow, prisms can help restore fusion and reduce the suppression scotoma by facilitating sensory stimulation from the deviated eye.

While prisms may not reverse suppression entirely, they can play a supportive role in vision therapy or post-surgical rehabilitation by promoting binocularity [29].

Gaps in Current Research and Future Directions

Despite advances in the understanding and treatment of suppression, several gaps remain:

- Lack of standardized protocols for diagnosing and quantifying suppression. Most tests are subjective and require patient cooperation, which limits their reliability in young or cognitively impaired patients.
- Limited long-term studies on binocular therapies and suppression outcomes in adults. Although new evidence supports binocular therapy in adults, questions remain about the durability and generalizability of these effects.
- Insufficient comparative studies between occlusion, vision therapy, and combined approaches in different suppression types and clinical populations.
- Emerging techniques like virtual reality (VR)-based therapies and neuroplasticity-driven interventions show promise but require further investigation to validate their efficacy and integration into routine care.

Future research should prioritize large-scale randomized trials, long-term outcome measures, and the development of objective, quantitative suppression assessment tools. Integrating imaging technologies (e.g., fMRI, VEPs) with clinical findings may also improve understanding of the neural basis of suppression and enhance individualized treatment planning.

## CONCLUSION

Suppression is a complex sensory adaptation that plays a pivotal role in the development and maintenance of binocular vision disorders. It can be classified into facultative, obligatory, central, and peripheral types—each with distinct clinical presentations and implications. The evidence consistently indicates that suppression is commonly associated with strabismus, amblyopia, anisometropia, and various non-strabismic binocular vision anomalies such as convergence insufficiency. The nature and depth of suppression vary according to the underlying pathology, duration of the visual anomaly, and the age of onset.

A wide range of diagnostic tools, including the cover test, Worth 4-dot test, and Bagolini lenses, are available to detect and evaluate suppression, with newer dichoptic technologies offering more precise quantification.

Treatment approaches such as occlusion therapy, vision therapy, and prism correction have shown varying degrees of effectiveness, with vision therapy emerging as particularly promising in reducing suppression and restoring binocular function.

**Implications for Clinical Practice and Future Research**

From a clinical standpoint, accurate detection and classification of suppression are essential for individualized management. Clinicians should employ multiple diagnostic techniques to assess suppression depth and location, especially in pediatric populations or complex binocular disorders. Early intervention remains critical to prevent long-term visual deficits, particularly in amblyopia and strabismus.

In terms of treatment, an integrative approach that combines occlusion, vision therapy, and prism adaptation should be considered, especially in cases with both motor and sensory anomalies. The increasing availability of digital and home-based dichoptic training tools offers new avenues for patient-centered therapy.

- Despite advances, gaps remain in standardized diagnostic criteria, long-term outcome studies, and adult suppression management. Future research should focus on:
- Developing objective, quantitative suppression assessment tools
- Conducting large-scale, randomized trials comparing therapeutic modalities
- Exploring the neurophysiological underpinnings of suppression using imaging and electrophysiological methods.
- Evaluating innovative digital therapies (e.g., virtual reality and gamified interventions)
- By addressing these areas, the field can move toward more precise diagnostics, tailored interventions, and ultimately better visual and functional outcomes for patients affected by suppression and related binocular vision disorders.

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