Diplopia and Confusion in Visual Field Rehabilitation
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Disclosure Statement:

- I have a patent for the peripheral prisms that I will mention in the talk
  Assigned to Schepens and Licensed
- I did and do consult for a number of companies on issues that may be related to binocular vision:
  - Google, Nintendo, Oculus (Facebook), VisionCare, Alcon, Evergaze, Visio, Intel

Double Vision Occurs When eyes are not aligned

- Eyes are not aligned in strabismus
- Eyes are not aligned if high power prism is placed in front of one eye
  - Images of objects fall on different, non-corresponding, retinal loci in both eyes
  - Resulting in different perceived directions

How Does Double Vision Look?

According to NHS (UK)  
According to Wikipedia

Why is one image faint? Suppression? No. PPT transparency

Double vision of real scene is not perceived with faint low contrast
Both images are perceived with full contrast

I have not found a way to represent it correctly in ppt or photoshop

A patient with multiple sclerosis provided more accurate ppt illustration by illustrating a transparent object

http://www.williamsoneyeinstitute.com/cataracts-blog/  
Picked up by a cataract blog incorrectly – Double vision in cataract is monocular and usually noted only for lights in the dark
Perceived contrast is better depicted in this drawing. Also a reminder that double vision can be vertical but only one nose and one right ear! Double vision is very disturbing and annoying!

Suicide prevention website: University Life Café

I’ll represent images perceived by both eyes using cartoon illustrations. Because it is particularly good for illustrating field loss but it also preserves the high contrast.

Right EsoTropia

Double Vision

Diplopia – the same object (woman) perceived in two different directions

Confusion – Two objects (right hand & back pocket) perceived in the same direction

Diplopia is everywhere

Binocular Confusion is Everywhere

Diplopia – the same object perceived in two different directions

Binocular Confusion – Two objects perceived in the same direction
Diplopia and Confusion

- For years I stated in lectures that Diplopia and Confusion are conjoined twins; always together and not separable
- Today I’ll show that I was wrong; in low vision one can have Diplopia without Confusion or Confusion without Diplopia
  - In cases of field loss and with use of partial prisms
- Diplopia and confusion can be monocular
  - Today discussing only the binocular varieties
- Double vision can be central and peripheral

Even with Normal Full Fields the Statement is Not True

Field of View with Left Exotropia

Percept with 20º Left Exotropia

Double Vision

Many objects are diplopic and many are confused

Percept with 20º Left Exotropia

No Diplopia and no Confusion

Pond is in Confusion with the cub but no Diplopia
Roles of Diplopia & Confusion in Binocular Vision

- Diplopia serves as a stimulus for convergence and fusion
  - Convergence brings an object to corresponding points
- Confusion has no role in convergence
- Confusion is the stimulus for rivalry
  - Confusion can be considered rivalry with extreme predominance
  - Can diplopia cause suppression?
    - Can be tested if we can have diplopia without confusion

Roles of Confusion & Diplopia in Field Expansion

- Confusion is our main tool for field expansion
- Diplopia has no visual field benefit
  - It is annoying and disturbing
- Double vision is less bothersome in the periphery
  - Physiological diplopia (and confusion)
- Confusion and/or diplopia may be limited to only part of the field

Confusion without diplopia in RP with strabismus (LET)

This patient’s field is expanded
There is no diplopia, as no object can be seen by both eyes
Confusion is limited to central field – trivial case
When Confusion occurs without Diplopia it is Noticeable and Bothersome Especially Centrally

Nevertheless, it does expand the field. We created the same effect with prisms to expand the field of patients with Tunnel vision and no strabismus

Tri-field Prism Glasses
Were found useful by 25% of patients, but central confusion is difficult to bear

Confusion without diplopia on left gaze
Also expanded field

With Tri-field prisms over right eye confusion without diplopia

Similar Field Expansion Effect in Right Hemianopia with Strabismus (RXT)
Confusion with little diplopia

Binocular Goldmann Field

Dichoptic Central Field Restricted by Shutters

Left eye Only  Right eye Only  Diplopia

Diplopia without Confusion

Naturally occurring in Bi-Temporal Hemianopia

Binocular View with Bi-Temporal Hemianopia

Minimal Field Loss

With Bi-Temporal Hemianopia

• No functioning corresponding points exist
• Pre-existing phoria manifests as tropia
  – Results in diplopia without confusion
• Without confusion no way for the system to sense the misalignment of the eyes
  – Seeing 2 samples of something is natural
• No way to use fusion to align the eyes

Bi-Temporal Hemianopia with R Exophoria

Fixation target

Bi-Temporal Hemianopia with R Exophoria

Fixation target
BiTemporal Hemianopia with R Exophoria

Double vision – Diplopia

Only small part of the field is diplopic

The exophoria manifests as **exotropia** because the diplopic images cannot move to **corresponding** points

**The New York Times**

Try reading the text

Unknown's Painting Hangs Out at Modern for a Weekend

BiTemporal Hemianopia with R Hyperphoria

“..described and illustrated by patient with bitemporal hemianopia”

Corrected from illustration in Shainberg, et al. 1995 American Orthoptics J.

Not a true diplopia as in lateral heterophoria case

I’d like to define this as **Split Diplopia:**

Two parts of the same conceptual object are seen in two different directions

Split diplopia occurs horizontally

In Anti Symmetric Altitudinal Hemianopia

Here too no corresponding points in both eyes

Here vertical phoria will result in real diplopia


Horizontal Split Diplopia

With use of binocular yoked split prisms

Split diplopia comes with split confusion but that is rarely noticed

Kohler I. (1964) The formation and transformation of the perceptual world. PsychoI Issues

Right Homonymous Hemianopia

Dichoptic Binocular Field
Right H Hemianopia with Right Exotropia

Confusion without Diplopia in Part of the Field
Field Expansion
Naturally occurring in Congenital Hemianopia
“Panoramic vision”

Apfelbaum et al. (2013) Considering apical scotomas, confusion, and diplopia when prescribing prisms for homonymous hemianopia. TVST

View with Right Hemianopia & Right Exotropia

Left Eye Fixation
Fixated object is always diplopic
Central Diplopia - Bothersome

Double Vision Diplopia & Confusion
Field Expansion by Confusion

View with Right Hemianopia & Right Esotropia

Confusion only
No peri-central Diplopia
But no field expansion

View to the Right Results in Bothersome Confusion

With view to the right & slightly higher angle of esotropia
The fixated woman is confused with the man ahead
This is as bothersome as diplopia or more

View with Right Hemianopia & Right Esotropia

Confusion only
No peri-central Diplopia
But no field expansion

View from larger distance Results in Bothersome Confusion

This will also happen a little farther away (earlier)
Confusion can be terrible or inconsequential
Intelligent patient can learn to control this by changing distance and fixation
Diplopia is Always Noticed

- In full field strabismus Confusion and Diplopia coexist
  - Diplopia is always reported
  - Confusion is rarely reported
- Why?
- Diplopia of fixated object is always present
- Confusion of fixated object is present only occasionally, when an object of interest happens to be at the right eccentricity

Hemianopia & Tropia with ARC

- About 24 cases of teenagers reported many with documented ARC
  - ARC: Abnormal Retinal Correspondence
  - ARC eliminate the confusion and diplopia
- Surgeons usually do not operate on exotropes with hemianopia
  - As that results in loss of the field expansion

Right H Hemianopia & Right Exotropia

With ARC

No diplopia  
Field Expansion 
No Confusion

Unilateral Sector Prisms

Using Fresnel Press-on™ Prisms – 3M

- Prism on one lens only on side of the field loss
- Most positions of gaze-no effect at all
- On left gaze - ?

Left Hemianopia

Visual Field – With Large Gaze Shift

With 20Δ Sector prisms
Gaze shifted 20° into the Prism

View with gaze center
With unilateral sector prism 20Δ

Expanded Field

No effect of prism
**View of scene with gaze right**

No effect of prism

**View with gaze center**

No effect of prism

**View with 20° gaze left – No Prism**

**View with 20° gaze left into prism**

Diplopia

Expansion-Confusion in blue

Diplopia & Confusion are bothersome centrally

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**Peripheral Prism**

- High power Prism segments on upper & lower parts of the spectacle lens
- Users always look through central, prism-free area; No central double vision
- Prisms on left lens Base left for left hemianopia
Peripheral prism (57Δ) in primary gaze

OPS
Outward Prism Serration

Expansion
Diplopia

Apical scotoma can eliminate diplopia if prism size is just right

EPS
Eyeward Prism Serration

Expansion
Confusion

Effect of Prism Apex Position on Diplopia in Primary Gaze

What happens with change in eye position?

View with gaze 5° left (standard fit)

OPS
Outward Prism Serration

Expansion
Diplopia

EPS
Eyeward Prism Serration

Expansion
Confusion

Peripheral prism (57Δ) in primary gaze

Diplopia
Expansion
Confusion

Peripheral prism (57Δ) in primary gaze

Diplopia
Expansion
Confusion

Peripheral prism (57Δ) in primary gaze

Diplopia
Expansion
Confusion

Peripheral prism (57Δ) in primary gaze

Diplopia
Expansion
Confusion
Conclusions

• Confusion is the mechanism for field expansion
• Diplopia is of no value in this process
  – Prism designs should induce confusion and reduce or eliminate diplopia
• Eye movements interact with both diplopia & confusion
  – Should be considered

Conclusions

• Peripheral double vision is familiar
  – Easy to adapt to
  – Better to use peripheral confusion
• Designing and selecting parameters for prism correction can be complex
  – I have not addressed other variables
    • spurious reflections, distortions, rivalry

Conclusions

• With field loss or partial prisms diplopia and confusion may be separable
• Separation of Confusion and Diplopia should enable new ways to study binocular vision
  – i.e., can diplopia without confusion induce suppression?

Thank You

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