Macular Carotenoids and Visual Performance in Sports

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Disclosures

- Paid speaker for Abbott Nutrition
- Paid speaker for Industrial Organica
- Paid speaker for MacuHealth
- Paid speaker for Stauber USA

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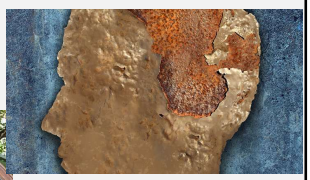
The Oxygen Paradox

Although indispensable for life, oxygen can be toxic.

- Reactive oxygen species (e.g. singlet oxygen, superoxide radicals)
  - Oxidative stress



Oxidation, sped along by an electrolyte (salt)

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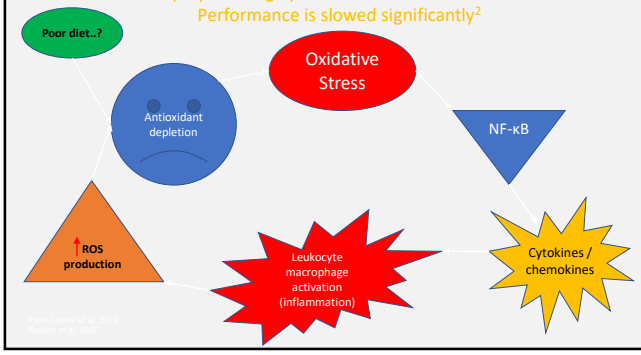
The self-perpetuating cycle of oxidation and inflammation[1]. Performance is slowed significantly[2]



From Leone et al. 2013
Bryden et al. 2007

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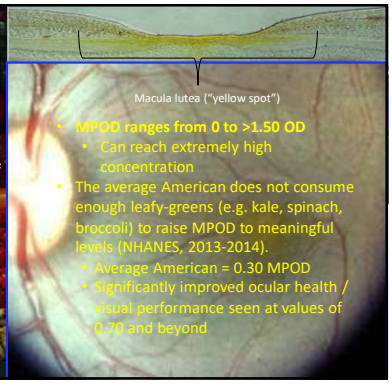
Lutein, Zeaxanthin, & Mesozeaxanthin

- **Carotenoids**
- Pigments that give fruits and vegetables their color
- Exceptional antioxidants
  - *Xanthophyll* carotenoids capable of *triplet excitation transfer*
    - Can quench free-radical oxygen, regenerate
- Lutein, zeaxanthin, and mesozeaxanthin appear yellow-orange…absorb harmful blue light (see figure on right)
- Combine to form "macular pigment" in the retina



- MPOD ranges from 0 to >1.50 OD
  - Can reach extremely high concentration
- The average American does not consume enough leafy-greens (e.g. kale, spinach, broccoli) to raise MPOD to meaningful levels (NHANES, 2013-2014).
  - Average American = 0.30 MPOD
  - Significantly improved ocular health / visual performance seen at values of 0.70 and beyond

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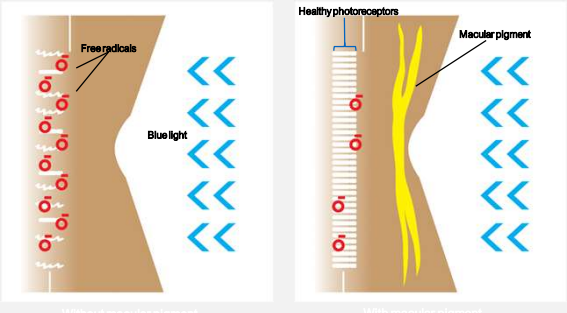
MPOD: Oxidation / inflammation feedback inhibited



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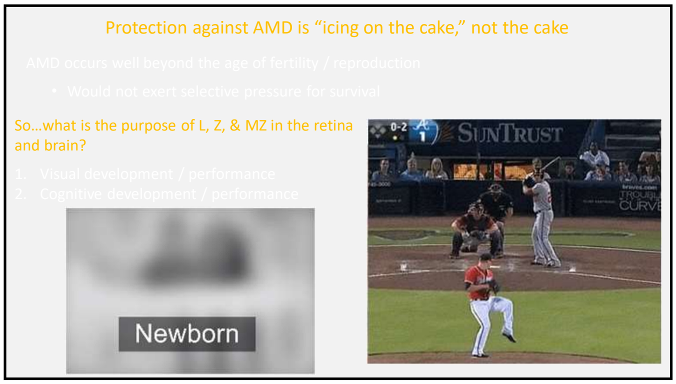
Protection against AMD is "icing on the cake," not the cake
AMD occurs well beyond the age of fertility / reproduction
• Would not exert selective pressure for survival
So…what is the purpose of L, Z, & MZ in the retina and brain?
1. Visual development / performance
2. Cognitive development / performance
Newborn
0-2
SunTrust

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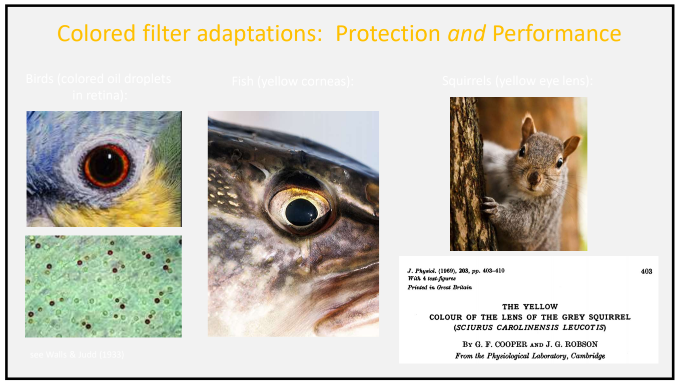
Colored filter adaptations: Protection and Performance
Birds (colored oil droplets in retina):
Fish (yellow corneas):
Squirrels (yellow eye lens):
J. Physiol. (1969), 203, pp. 403–410
With 4 text-figures
Printed in Great Britain
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THE YELLOW
COLOUR OF THE LENS OF THE GREY SQUIRREL
(SCIURUS CAROLINENSIS LEUCOTIS)
By G. F. COOPER and J. G. ROBSON
From the Physiological Laboratory, Cambridge
see Walls & Judd (1933)

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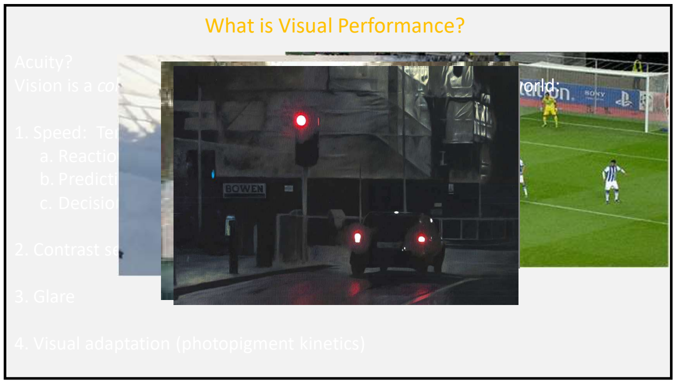
What is Visual Performance?
Acuity?
3. Glare
4. Visual adaptation (photopigment kinetics)
BOWEN

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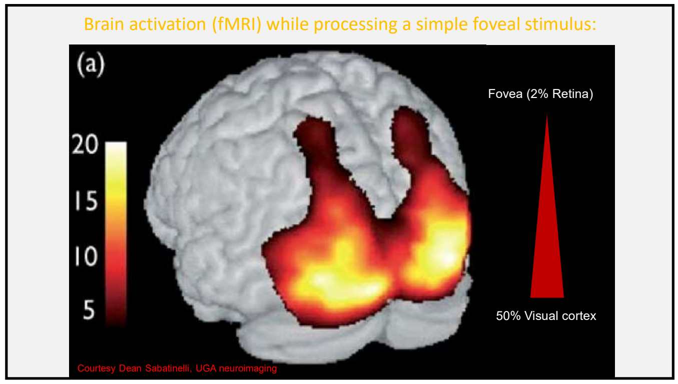
Brain activation (fMRI) while processing a simple foveal stimulus:
(a)
20
15
10
5
Fovea (2% Retina)
50% Visual cortex
Courtesy Dean Sabatinelli, UGA neuroimaging

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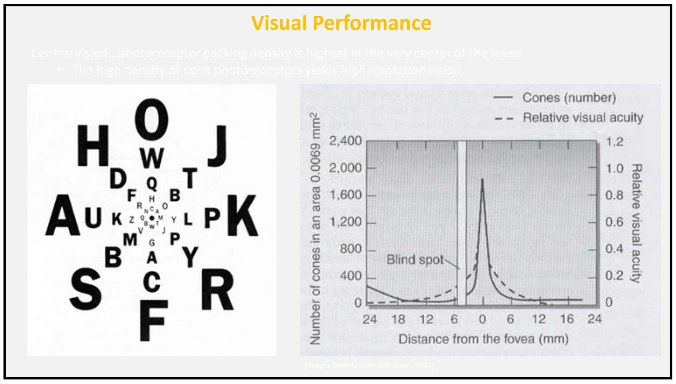
Visual Performance
Central vision…photoreceptor packing density is highest in the very center of the fovea.
• The high density of cone photoreceptors yields high resolution vision.
Cones (number)
Relative visual acuity
Number of cones in an area 0.0069 mm²
Relative visual acuity
Blind spot
Distance from the fovea (mm)
(images from Sekuler and Blake, 2002)

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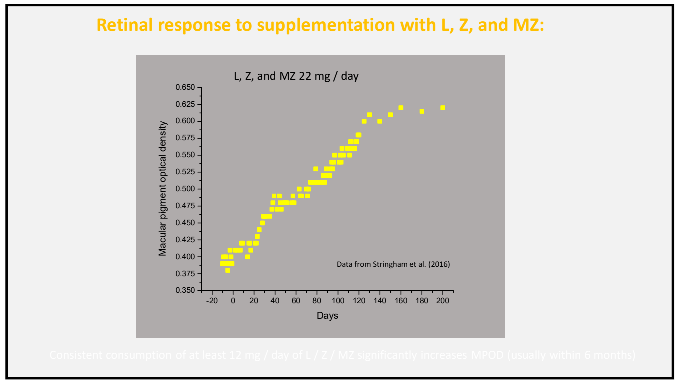
Retinal response to supplementation with L, Z, and MZ:
L, Z, and MZ 22 mg / day
Macular pigment optical density
Days
Data from Stringham et al. (2016)
Consistent consumption of at least 12 mg / day of L / Z / MZ significantly increases MPOD (usually within 6 months)

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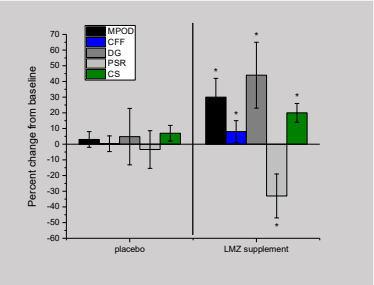
Visual performance and L, Z, & MZ supplementation (6 months):

MPOD increased significantly, and several parameters of visual performance were found to improve:

- **Speed of visual processing** (CFF)
- **Disability glare** (DG): seeing "through" glare
- **Photostress recovery time** (PSR)
- **Contrast sensitivity** (CS)



From Stringham et al. 2017

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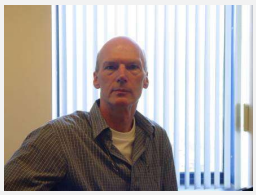
Glare Disability: Low vs. High MPOD
40% Improvement

High MPOD



Low MPOD

Based on data from Stringham et al. (2007)

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Macular carotenoid status and visual / cognitive performance in baseball players

1. Xavier University (Cincinnati, OH) baseball data
2. University of Georgia (Athens, GA) supplementation case study

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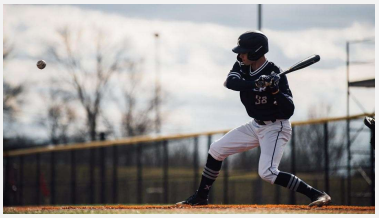
Xavier baseball team testing (11-9-2019)



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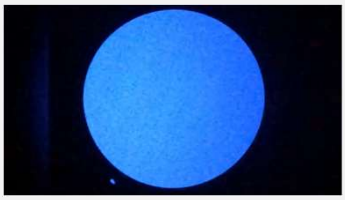
Measurement of MPOD / CFF: Flicker Photometry



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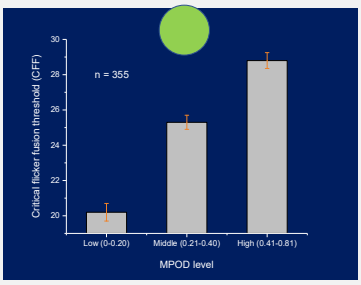
CFF: Strongly related to MPOD



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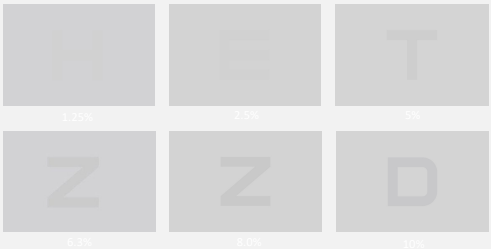
Measurement of Contrast Sensitivity



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Xavier Baseball: Overall visual measures summary

N = 20
Age = 20.33 +/- 1.22

Measure	Mean	Standard Deviation
Visual Acuity (ETDRS letters)	90.85	3.09
MPOD	0.481	0.15
Central Visual Processing Speed (CFF, Hz)	27.15	2.32
Peripheral Visual Processing Speed (CFF, Hz)	29.005	4.40
Contrast Sensitivity Threshold (6 cpd)	1.66%	0.386

These are averages +/- variation (i.e. standard deviation) from player to player. Some notes:

1. Visual Acuity. Overall, the players have good visual acuity – better than 20/20 (90 letters = roughly 20/16).
2. MPOD. The value of 0.481 is above the average for the general population. We start to see significant visual performance improvements at about 0.70 – 0.80.
3. Central visual processing speed. This is a very important measure of visual performance; high-level athletes should probably be at 30 and above.
4. Peripheral visual processing speed. This influences reaction time, and timing / hand-eye coordination. The higher, the better.
5. Contrast sensitivity threshold (6 cpd). The measure at 6 cycles / degree captures information near the peak of the contrast sensitivity function and is influenced significantly by MPOD. Lower thresholds are better in this case; we typically see values of 1.2% and lower for those with high MPOD.

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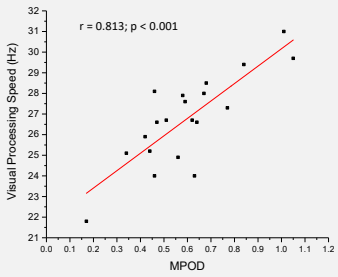
MPOD & Central Visual Processing Speed



Relationship between MPOD and central visual processing speed. This is a strongly significant correlation, and as can be seen in the graph, a player's MPOD predicts processing speed.

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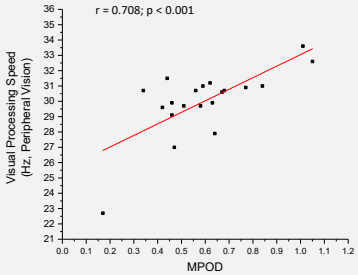
MPOD & Peripheral Visual Processing Speed



Relationship between ***peripheral*** visual processing speed and macular pigment. As with the previous figure, the higher a player's MPOD, the faster his peripheral visual processing speed.

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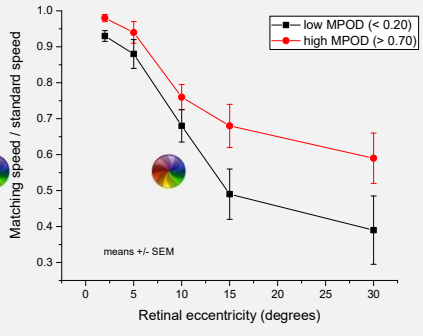
Peripheral motion detection: Those with higher MPOD are significantly more accurate

AF pilots, special operations personnel



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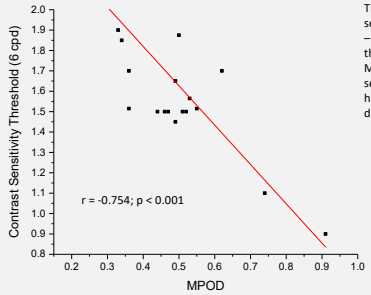

This figure shows how MPOD and contrast sensitivity thresholds are significantly related – note that lower contrast sensitivity thresholds are better. Players with higher MPOD have significantly lower contrast sensitivity thresholds; the players with the highest MPOD values in the graph are a dramatic example of this phenomenon.

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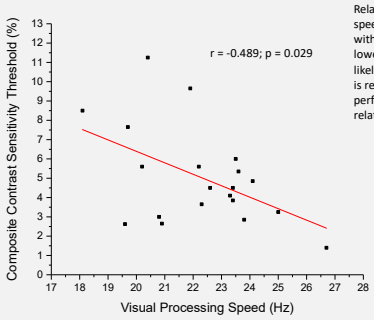

Relationship between central visual processing speed and contrast sensitivity threshold. Players with faster visual processing speed tend to have lower contrast sensitivity thresholds. The most likely explanation is that each of these variables is related to MPOD (which leads to improved performance in both domains) and mediates the relationship shown in the graph.

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Case study: UGA baseball player (3rd baseman)

Subject:

20 YOWM
UGA baseball player
BMI: 27.4
20/15 OU SC
MPOD: 0.17

Complains of sensitivity to bright light, difficulty sometimes visually "picking up" ball after leaving pitcher's hand

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CAT: Coincidence anticipation timing

White LEDs (separated by less than 1 inch) are sequentially illuminated

Exact start time cannot be predicted

Speed of each trial is also random (*see video link)

Subject's task is to push the response button when s(he) believes the light will be coincident with the white strip of tape (see picture)

Very difficult…average accurate performance: ~40-50%

"Correct" responses are those where the timing of the button press corresponds to the light directly in line with the white tape or those immediately to the left or right.

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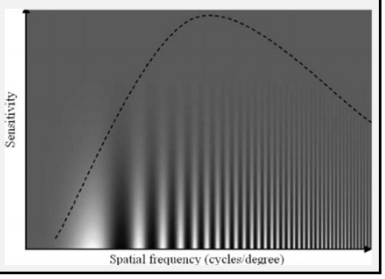
Visual performance data at baseline:

Contrast threshold for 6 cpd at baseline: 3.0%
Photostress recovery time: 11.9 seconds
Nominal disability glare radiance: 71.6
CFF: 23.75 Hz
CAT accuracy: 59.4%



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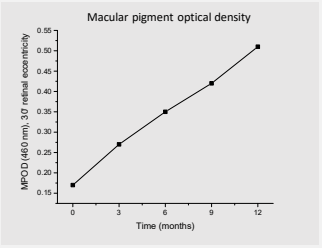
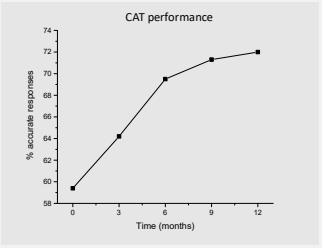
Results from 1-year, 22 mg / day L, Z, & MZ intervention





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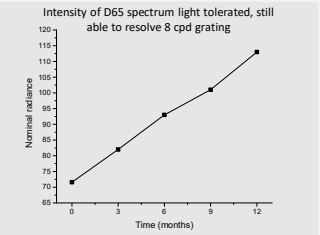
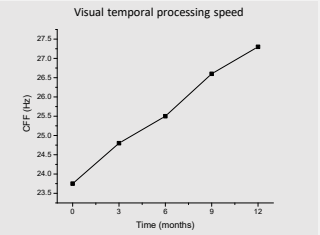
Results from 1-year, 22 mg / day L, Z, & MZ intervention





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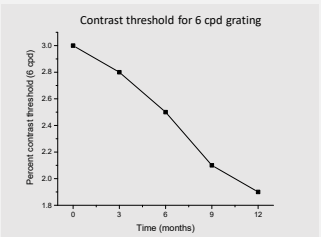
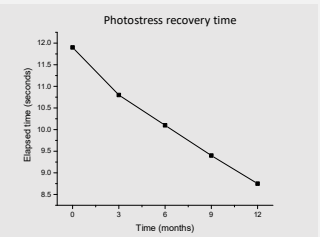
Results from 1-year, 22 mg / day L, Z, & MZ intervention





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Anecdotal observations:

"I can see the ball better. A lot of times I can see the general spin of the ball right out of the pitcher's hand"

"Much easier to deal with the sun, and stadium lighting during night games.

"On bang-bang plays, things seem to almost slow down – I can really focus on hard-pull ground balls"

"I feel like I have a lot more control – you know, like I am really there, in the moment. Makes me feel a lot more confident"

Game-based metrics

Parameter	Before supplementation (2012)	After supplementation (2013)
Batting average	.279	.311
Strikeout percentage	13.3%	9.6%
Walk percentage	7.1%	9.85%
Fielding percentage	.928	.956

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Conclusions

- Macular carotenoid status influences several parameters of visual performance
  - Speed of processing / timing / eye-hand coordination
  - Contrast sensitivity
  - Visual performance in glare, recovery from glare
- All of these can benefit sports performance
  - Any sport that relies on visual input…!
- Athletes tend to have relatively low MPOD
  - Appear to respond very favorably to macular carotenoid supplementation
    - Perhaps due to good overall health
    - Can augment MPOD significantly in short time period (~ 6 months – 1 year)
      - Noticeable effects (assuming consistent supplementation regimen) as quickly as 3 months

These effects can facilitate a conversation with patients about nutrition / supplementation

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