Interpreting visual field losses – pitfalls and conundrums

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Learning objectives

By the end of the talk, you will be able to:

- Understand the importance of visual field test selection for glaucoma
- Develop a systematic approach to assessing visual field reliability
- Understand the role of emerging technologies, such as alternative testing platforms and home monitoring, in the care of patients with glaucoma

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PART 1: Test selection for glaucoma

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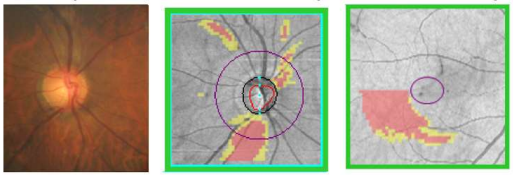
Clinical problem: what test grid should I use?

ONH photo | RNFL deviation map | GCA deviation map



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Visual field test grids

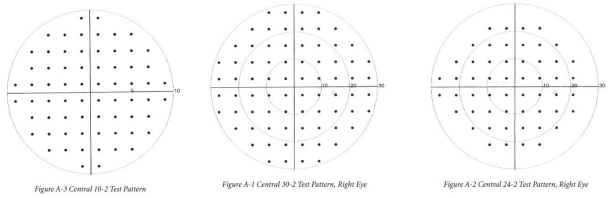

Figure A-3 Central 10-2 Test Pattern

Figure A-1 Central 30-2 Test Pattern, Right Eye

Figure A-2 Central 24-2 Test Pattern, Right Eye

68 test points 2 degree spacing ~10 degrees	76 test points 6 degree spacing ~30 degrees	54 test points 6 degree spacing ~24 degrees + 2 nasal

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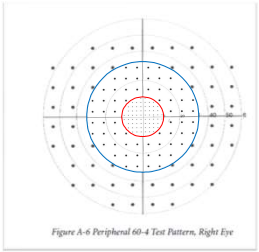
Visual field test grids



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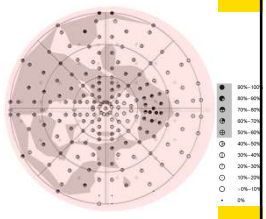
Visual field defects in glaucoma

- Early visual field defects in glaucoma have characteristically affected locations *(Schiefer et al 2010 IOVS)*
  - Nasal step
  - Paracentral
  - Arcuate (high and low)
- 24-2 Offers sufficient coverage of test locations predominantly affected in early glaucoma *(Khoury et al 1999 J Neuroophthalmol)*



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Limitations of the 24-2

- Inadequate sampling of central visual field *(De Moraes et al 2017 Ophthalmology; Grillo et al 2016 TVST)*
- Sparse sampling due to 6º test point spacing *(Ballae Ganeshrao et al 2015 Ophthalmology)*

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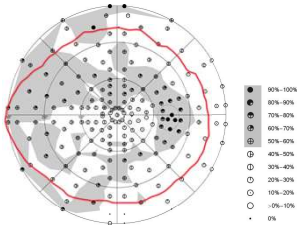
Should we use 10-2 instead?

- Current issues with 10-2 visual field testing
  - No widely accepted staging systems
  - Not interchangeable with 24-2 (but with similar global scores) *(Sullivan-Mee et al 2016 AJO)*
  - Evidence for "switching" between grids lacking – issues with clinical flow and progression analysis



Schiefer et al 2010 IOVS

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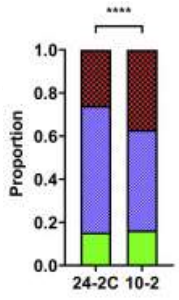
Evidence 24-2C vs 24-2 and 10-2

- 24-2 vs 24-2C *(Phu & Kalloniatis 2020 AJO)*
  - Global metrics (e.g. MD) – no difference
  - Proportion of central defects identified – no significant difference
  - Central structure-function – 24-2C slightly better
- 24-2C vs 10-2 *(Phu & Kalloniatis 2021)*
  - Global metrics (e.g. MD) – similar
  - Proportion of central defects identified – 10-2 superior
  - Central structure-function – 10-2 superior



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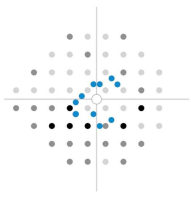
What about the 24-2C?

- Does NOT provide additional global information compared to 24-2
- Does NOT provide additional cluster information compared to 24-2
- Provides SOME additional information on central structure-function… but then loses out to 10-2



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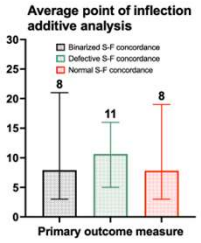
When to perform 10-2?

- There is a dose-dependent effect between test locations and defect detection
- 8-12 test locations added to the central ~8 degrees maximises concordance and minimises discordance *(Rafla, Kalloniatis & Phu, 2023 CXO)*
- No clear clinical guidelines



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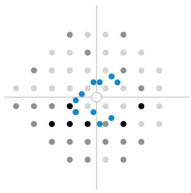
Current clinical recommendations

- 24-2 for overall identification of defects
- What is the role of 10-2?
  - "Detection"?
  - "Confirmation"?
  - "Monitoring"?



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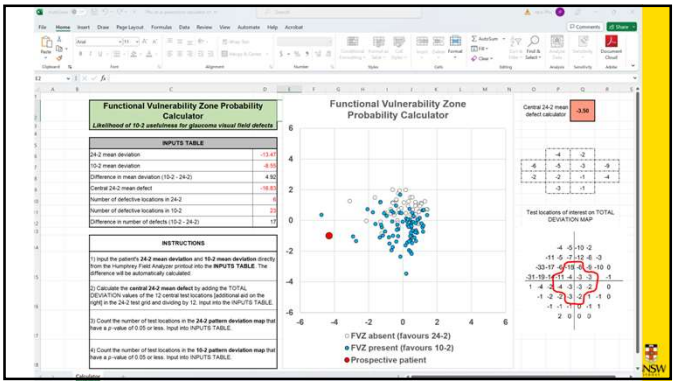

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PART 2: Visual field reliability – a systematic approach

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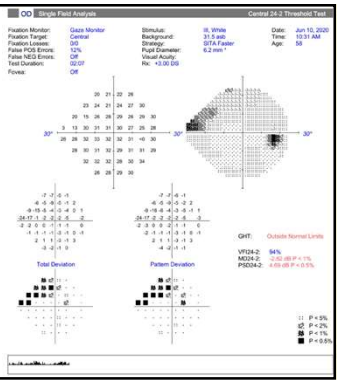
Reliability

- Maintain a systematic approach – same with visual fields
  - Patient ID
  - Correct date, time and protocol
  - Quality and reliability
  - Inspect each map and global indices
  - Qualitative and quantitative



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- Basic parameters
  - Correct patient ID
  - Correct test protocol
  - Correct date
  - "Reliability" (later)

OD | Single Field Analysis | Central 24-2 Threshold Test

Fixation Monitor:	Gaze/Blind Spot	Stimulus:	III, White	Date:	
Fixation Target:	Central	Background:	31.5 asb	Time:	
Fixation Losses:	0/11	Strategy:	SITA Faster	Age:	
False POS Errors:	12%	Pupil Diameter:	5.0 mm *		
False NEG Errors:	Off	Visual Acuity:			
Test Duration:	03:28	Rx:	+4.75 DS -1.25 DC X 91		
Fovea:	Off				

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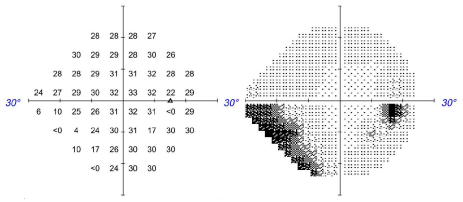
- Inspecting raw sensitivity values to identify patterns of defects and potential artefacts; greyscale should correlate



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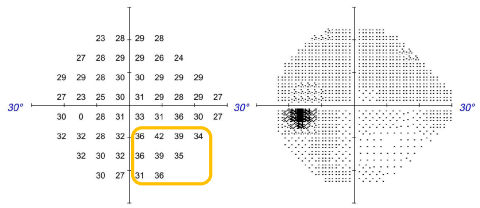
- Example of **abnormally high sensitivity** artefact *despite the false positive rate being <15%*



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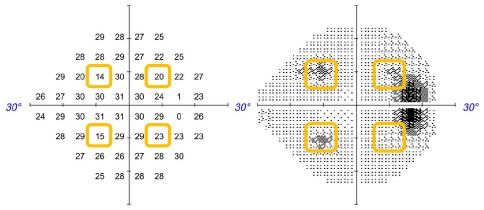
- Example of abnormally low sensitivity at the seeding points – ***seeding point errors***



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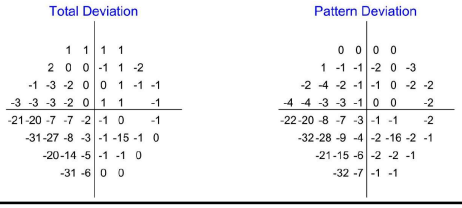
- Total deviation map = difference from age-match normal
- Pattern deviation map = difference after correcting for patient's own Hill of Vision



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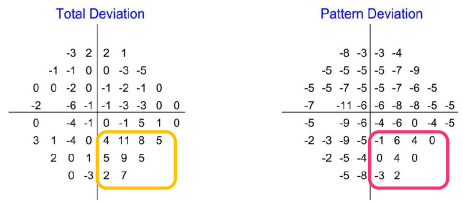
- Example of **abnormally high Hill of Vision** due to trigger happy behaviour



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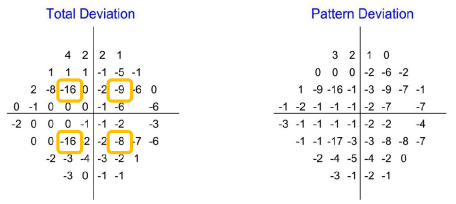
- Example of **abnormally low Hill of Vision** due to seeding point errors



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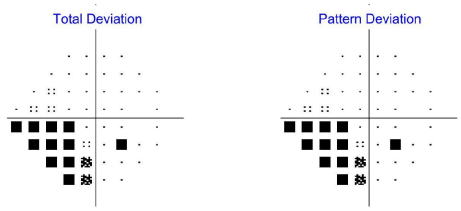
- Deviation maps: patterns of defects at **different levels of statistical significance** relative to normative distribution



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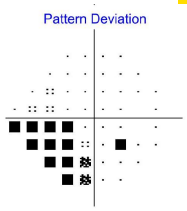
Printout

- Deviation maps: patterns of defects at **different levels of statistical significance** relative to normative distribution
- Commonly used cut-off: **3+ contiguous points at *p*<5%, of which at least 1 point is *p*<1%**
- Use descriptors for defects



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- MD = mean deviation = "average" sensitivity loss across test locations
  - VFI: similar principle
- PSD = pattern standard deviation = *variance* of sensitivity loss across test locations
- GHT = comparison of symmetric zones of test locations across the horizontal midline

GHT: Outside Normal Limits

VFI: 90%
MD24-2: -4.78 dB P < 1%
PSD24-2: 8.46 dB P < 0.5%

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Mean deviation

- Mean deviation
  - Typically used for staging glaucoma
  - Regarded a pseudo "continuous" scale of disease sensitivity loss and progression
  - Affected by factors affecting the whole visual field

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Pattern standard deviation

- Pattern standard deviation
  - Typically used for identifying "clusters" or regions of loss, highlighting **high variance** in visual field sensitivity
  - OHTS used this as a pseudo "cut-off" for glaucoma and glaucoma risk
  - Affected by factors affecting the **parts** of the visual field

		0	0	0	0			
		1	-1	-1	-2	0	-3	
	-2	-4	-2	-1	-1	0	-2	-2
-4	-4	-3	-3	-1	0	0		-2
-22	-20	-8	-7	-3	-1	-1		-2
	-32	-28	-9	-4	-2	-16	-2	-1
		-21	-15	-6	-2	-2	-1	
			-32	-7	-1	-1		

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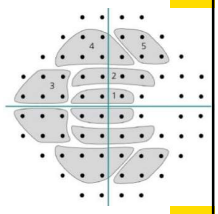
Glaucoma Hemifield Test

- Glaucoma Hemifield Test *(Asman & Heijl, 1992 Arch Ophthalmol)*
  - Compares **probability scores**, but does NOT assess sensitivity directly
  - Examines five symmetric zones that are typically described in glaucoma
  - Generally low sensitivity, high specificity in early disease and questionable utility in later glaucoma *(Stubeda et al 2022 AJO)*



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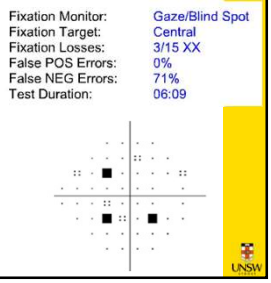
Visual field reliability

- Two ways of assessing
  - Quantitative
    - Fixation losses / gaze tracker deviations
    - False positives
    - False negatives
    - Short term fluctuations
  - Qualitative
    - Seeding point errors
    - Trigger happy behaviour
    - Inattention
    - Fatigue
    - Learning effect
    - Optical and refractive errors



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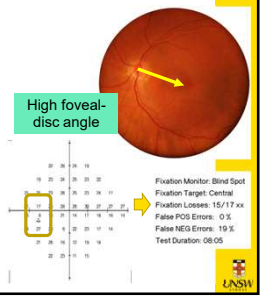
Fixation losses / gaze tracker deviations

- Heijl-Krakau "Blind spot" errors
- Limitations
  - Relies on accurate blind spot mapping at beginning of test
  - ~10-15 catch trials to characterise fixation – especially when using "traditional" cut-offs of 15-33%
  - Affected by disc morphology



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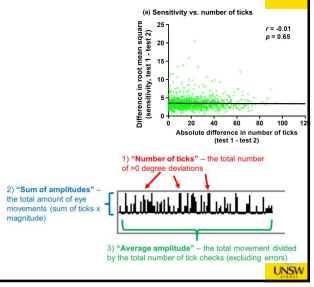
Fixation losses / gaze tracker deviations

- Infrared camera monitoring eye reflex (Purkinje) – largely continuous throughout test, so better than catch trials
- Output: a set of lines representing gaze deviations during the test
- Interpretation?

Phu and Kalloniatis 2022 Ophthalmic Physiol Opt



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Fixation losses / gaze tracker deviations

- Limitations
  - Typically only scalar, not vector quantity; resolution
  - Cannot infer when the deviation occurred, i.e. effect on sensitivity
  - Interpretation is largely qualitative
  - Generally poor correlations with output sensitivities and repeatability
  - Confounded by ocular media / reflection anomalies, e.g. IOLs
  - Interpretation relates to test density 10-2 vs 24-2

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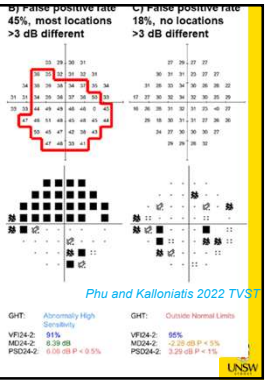
False positive rates

- Collected when a response is not expected (e.g. outside the response window)
  - Significance: supposed to represent "trigger happy behaviour"
- Current clinical cut-offs include 15% as recommended by the HFA
  - Note that this is one of the two default metrics reported in SITA-Faster



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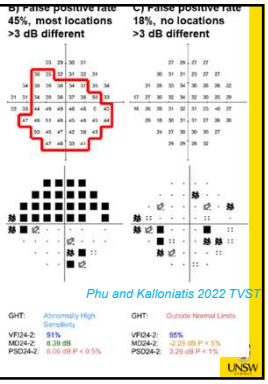
False positive rates

- Limitations
  - Limited catch trials throughout test
  - Little correlation with output sensitivity parameters of interest
  - Tendency for over-estimation in SITA-Faster = false data loss
- Practice point: trigger happy behaviour would be obvious on inspecting sensitivity maps



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False negative rate

- Defined as the lack of a response to a stimulus predicted to be visible to the observer (typically 6 dB more intense)
  - Significance: supposed to represent inattention, malingering or similar alterations in behaviour

Fixation Monitor:	Gaze/Blind Spot
Fixation Target:	Central
Fixation Losses:	3/15 XX
False POS Errors:	0%
False NEG Errors:	71%
Test Duration:	06:09

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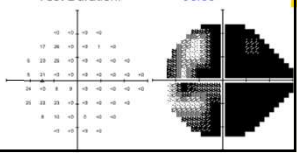
False negative rate

- Limitations *(Bengtsson & Heijl 2000 IOVS)*
  - Very little evidence of association with reliability
  - Instead, more related to disease severity: greater sensitivity loss = higher false negative rate
  - * Note: no longer reported when using SITA-Faster
- Recommendation: **do not use**

Fixation Monitor:	Gaze/Blind Spot
Fixation Target:	Central
Fixation Losses:	3/15 XX
False POS Errors:	0%
False NEG Errors:	71%
Test Duration:	06:09



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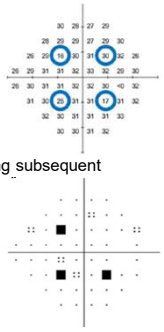
Seeding point errors

- Almost exclusively related to SITA-Faster
- Arises due to imprecise thresholding of or primary seeding points
  - Significance: falsely reduced sensitivity, affecting subsequent thresholds, progression and potentially global i



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Patterns of unreliability

- Trigger happy responses [falsely elevated hill of vision]
- Trial lens error [peripheral ring scotoma]
- Clover-leaf defect: inattention, malingering [peripheral defects]
- Seeding point errors
- Learning effect [improvement within test session]
- Refractive and optical issues: trial lenses, mask wear, dry eye [generalised blur]
- Must check ALL maps (sensitivity and deviation)

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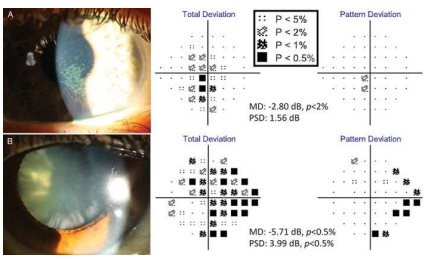
Patterns of unreliability



Phu et al 2017 Clin Exp Optom

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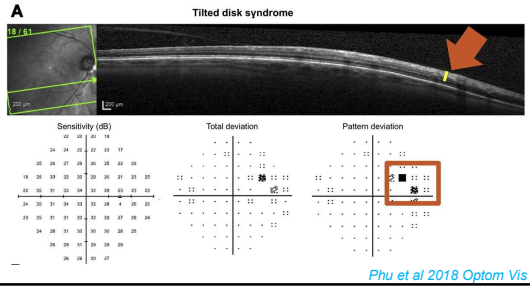
Patterns of unreliability



Phu et al 2018 Optom Vis Sci

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PART 3: Emerging technologies for visual field testing

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Issues with traditional perimetry

- Gold standard, but known limitations *(Skalicky & Kong, 2019 J Curr Glaucoma Pract)*
  - Cost
  - Size = office space requirements
  - Patient discomfort
- In principle, SAP is a psychophysically *simple* procedure – just a button press in response to simple stimuli

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Alternative test platforms

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Tablet-based perimetry

- Benefits
  - Relatively cheap
  - Portable
  - Not "worn"
  - Intuitive
  - No motion/VR sickness
- Limitations
  - "Flat" screen
  - Difficult to fix distance
  - Limited field of view

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VR-based perimetry

- Benefits
  - Relatively cheap
  - Portable
  - Fixed viewing distance
  - Full occlusion
  - Compensates for head and eye movements
- Limitations
  - May be difficult to correct refractive error
  - Motion/VR sickness
  - Needs to be "worn" – heavy

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"Screen"-based perimetry in general

- Anything that is not a projection system
- Limitations *(Ma et al, 2022 Surv Ophthalmol)*
  - Limited stimulus dynamic range due to outputs of the device – remember Weber's law and "dB"
  - Lack of standardisation amongst hardware and software
  - Stimulus jitter due to head movements
  - Distortion correction required (e.g. off-axis viewing of stimuli)

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"Screen"-based perimetry dynamic range

- Some brief numbers
- HFA
  - Maximum luminance output = 3813 cd.m-2
  - Background luminance = 10 cd.m-2
  - Decibel range = 0-50 dB
- Virtual Field
  - Maximum luminance output = 87 cd.m-2
  - Background luminance = 0.218 cd.m-2
  - Decibel range = 0-34 dB

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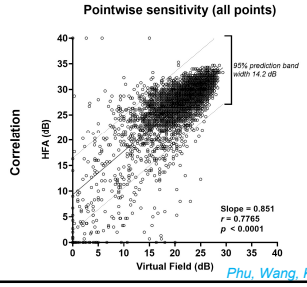
Not the same as SAP



Phu, Wang, Kalloniatis 2023 OPO

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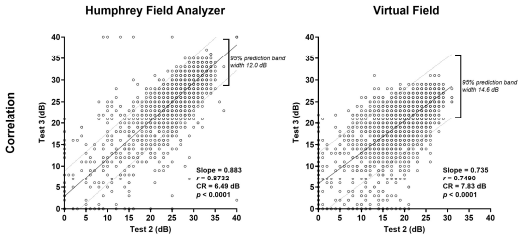
Not the same as SAP



Phu, Wang, Kalloniatis 2023 OPO

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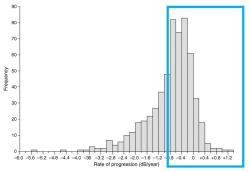
Role of portable perimetry: home testing

- When should we review patients with glaucoma?
  - Most patients progress slowly, e.g. -0.5 dB/year or slower – when would they show progression?
  - Goal is to detect rapid progressors?



Heijl et al 2009 Ophthalmology

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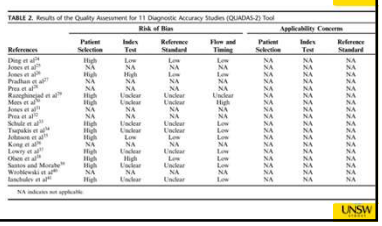
Role of portable perimetry: home testing

- Current evidence *(Daka et al 2022 J Glaucoma)*
  - "High acceptability" – risk of bias in current studies?
  - Large range in sensitivity (54-91%) and specificity (50-100%)
  - No current reference standard
  - Practical implications?



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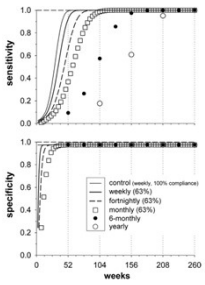
Role of portable perimetry: home testing

- Comments from *Anderson et al 2017 Ophthalmology*
  - More is better?
  - Having the "option" of testing seems to overcome issues with **variability** and low **compliance**
  - But this is with **very high volume testing**



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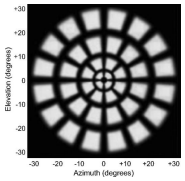
"Objective" perimetry?

- E.g. multifocal pupillographic objective perimetry
- Major assumptions made in terms of physiological response = subjective output
- Significant arguments about discordance between objective and subjective criteria



Carle et al 2011 IOVS

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Robot assistants in perimetry

- A "social" aspect to perimetry – superior to simple computer based feedback
- Allows engagement throughout the test
- Not significantly different in terms of output perimetric performance

McKendrick et al 2019 TVST

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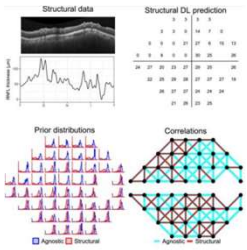
Bespoke perimetry

- Seeding perimetry test locations based on structural information, e.g. OCT *(Denniss et al 2013 TVST)*
- Newer algorithms also assisted by artificial intelligence



Montesano et al 2023 TVST

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Overall summary

- SAP remains an integral part of optometric practice
- Effective interpretation requires a good understanding of the technique, its printout and integration with other clinical findings
- Emerging technologies will provide more enablers to good clinical perimetry

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Thank you – questions?

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