Summation within and across shapes in central and peripheral vision

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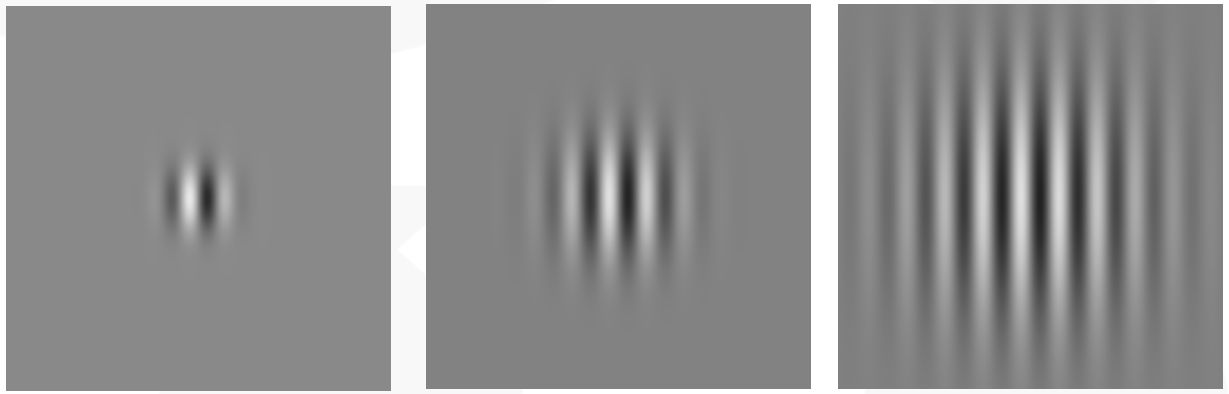
THE COLLEGE OF OPTOMETRISTS

UNIVERSITY OF PLYMOUTH

AVA Christmas Meeting 2019

Summation experiments

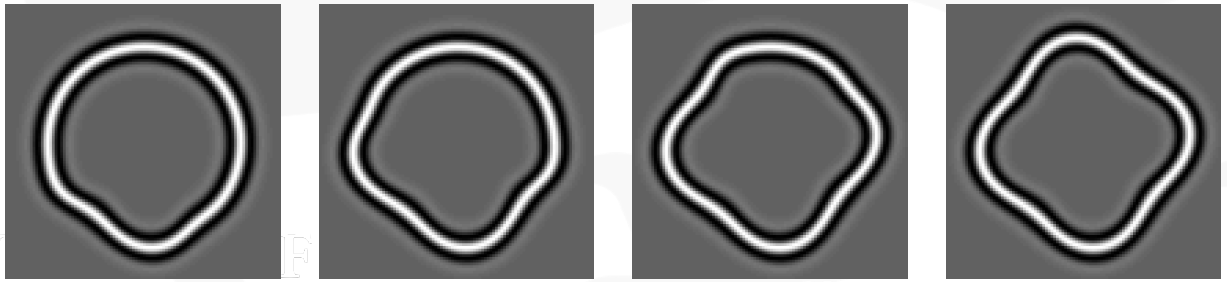
A



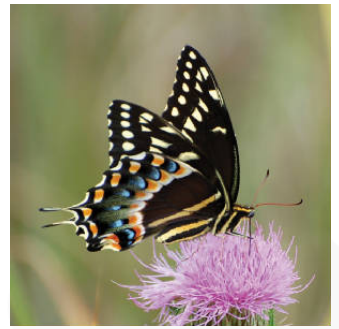
B

Change in number of modulated cycles

C



1 2 3 4



Kingdom, F.A.A., Baldwin, A. S., & Schmidtmann, G. (2015). Modeling probability and additive summation for detection across multiple mechanisms under the assumptions of signal detection theory. *Journal of vision*, *15*(5), 1-15.

Prins, N., & Kingdom, F. A. (2018). Applying the model-comparison approach to test specific research hypotheses in psychophysical research using the Palamedes Toolbox. *Frontiers in psychology*, *9*.

Stimuli

Frequency

Amplitude

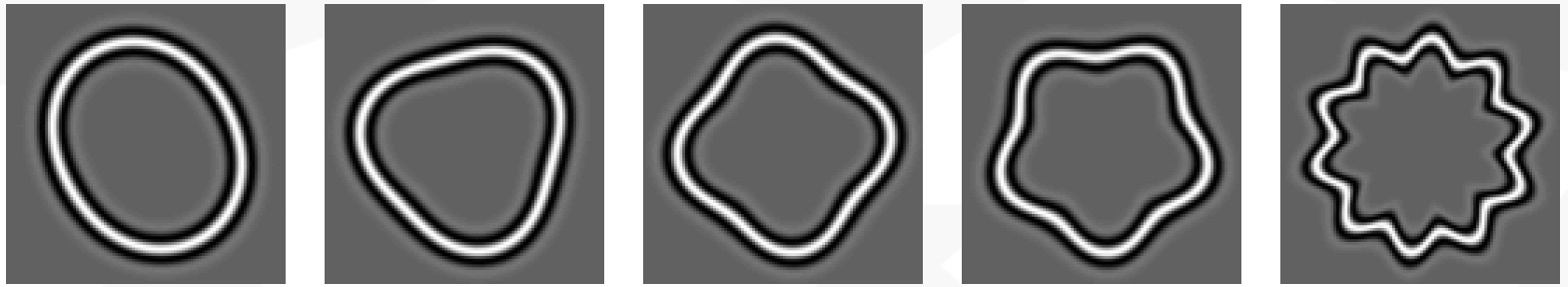
Phase / Orientation

$$r(\theta) = r_{mean}\left(1 + A(\omega\theta + \varphi)\right)$$

Wilkinson, F., Wilson, H. R., & Habak, C. (1998). Detection and recognition of radial frequency patterns. *Vision research*, *38*(22), 3555-3568.

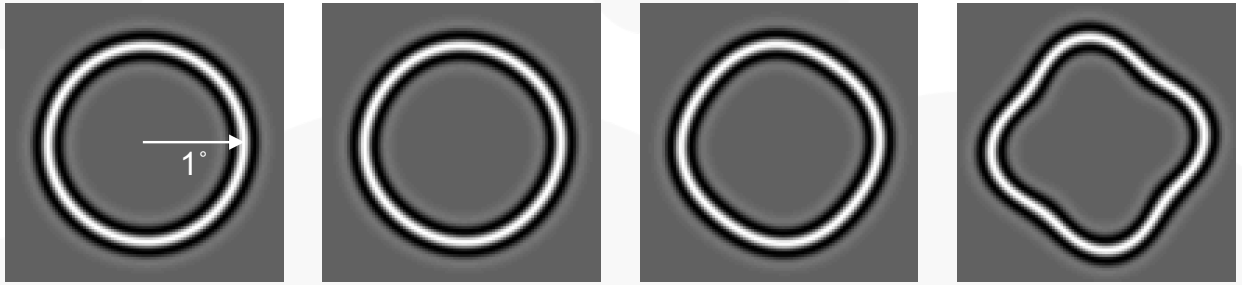
Stimuli

Change in frequency



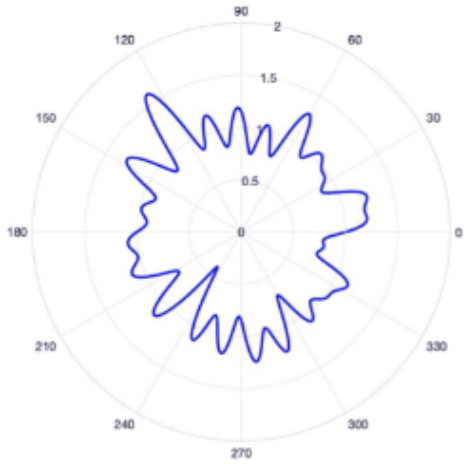
2 3 4 5 10

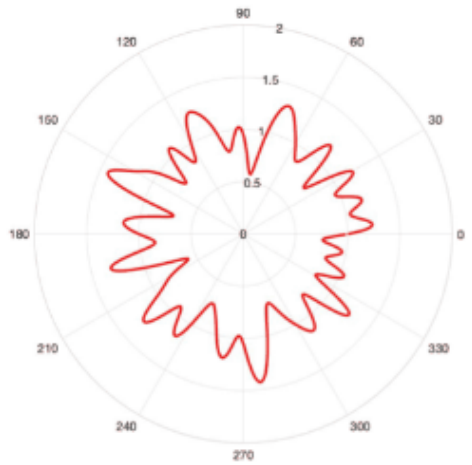
Change in amplitude



RF compounds – shape channels

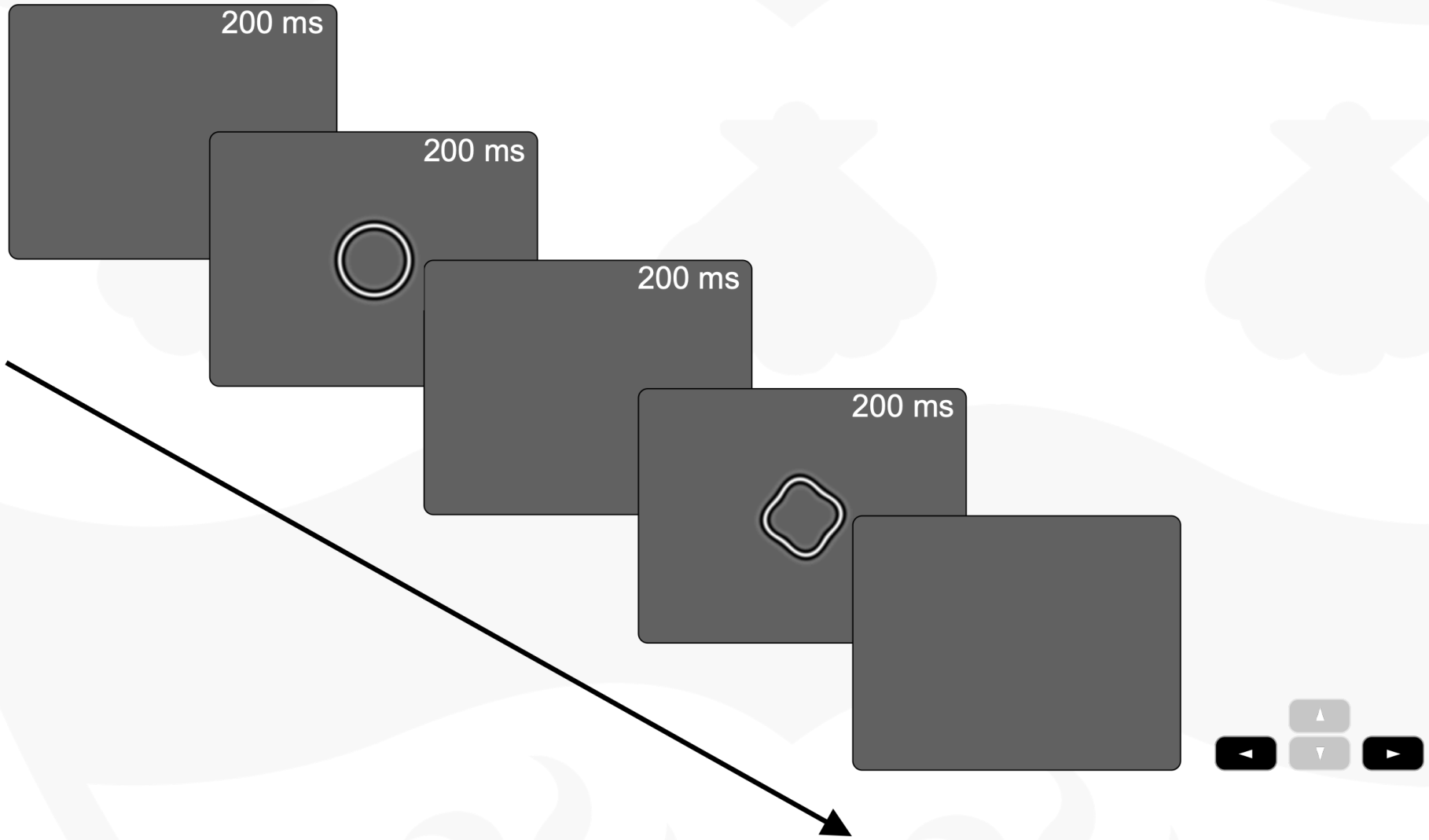
$$r(\theta) = r_{mean}\left(1 + \sum_{n}^{m} A_n sin(\omega_n \theta + \varphi_n)\right)$$



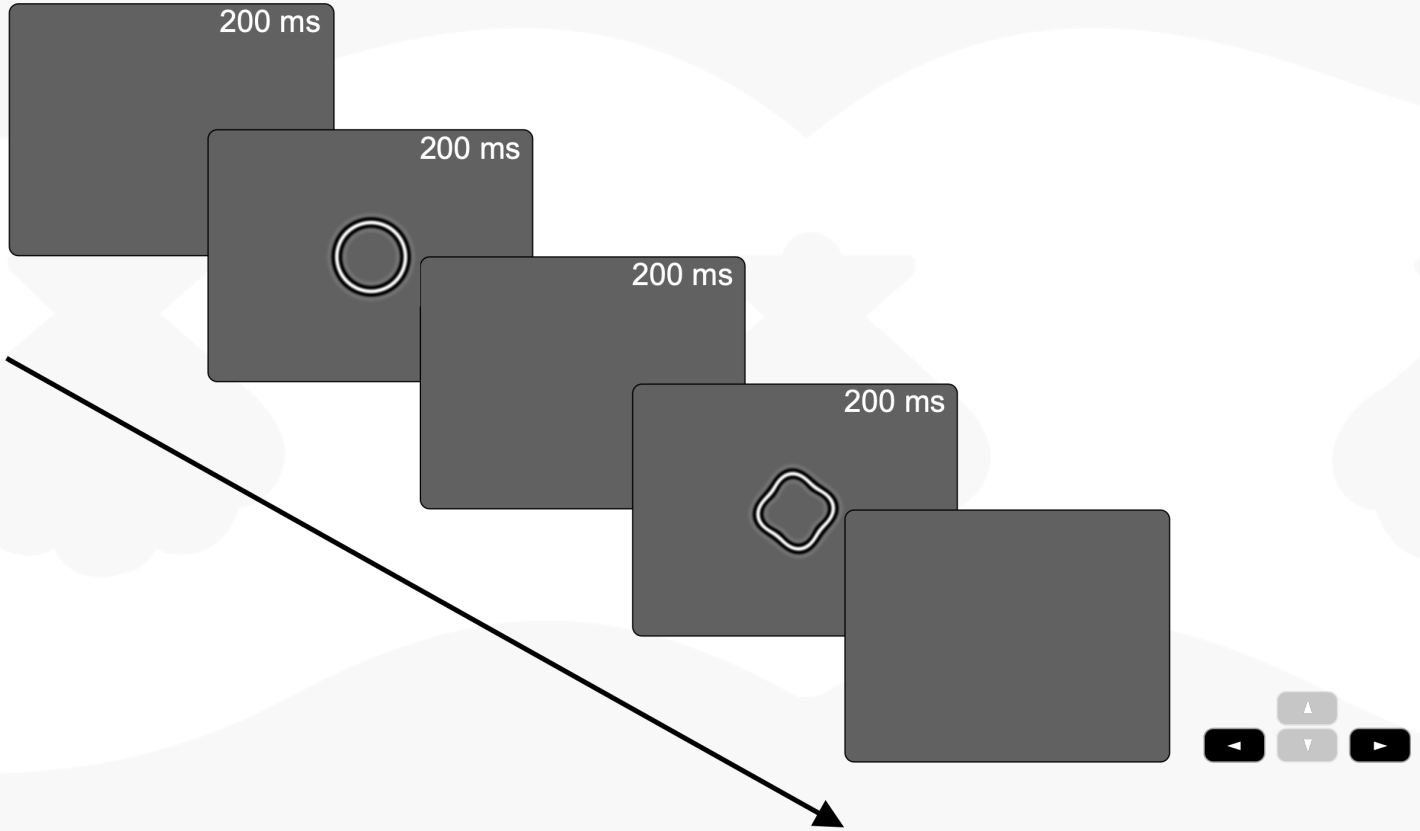


- Schmidtmann, G., & Fruend, I. (2019). Radial frequency patterns describe a small and perceptually distinct subset of all possible planar shapes. *Vision research*, *154*, 122-130.
- Schmidtmann, G., Kingdom, F. A., & Loffler, G. (2019). The processing of compound radial frequency patterns. *Vision research*, *161*, 63-74.

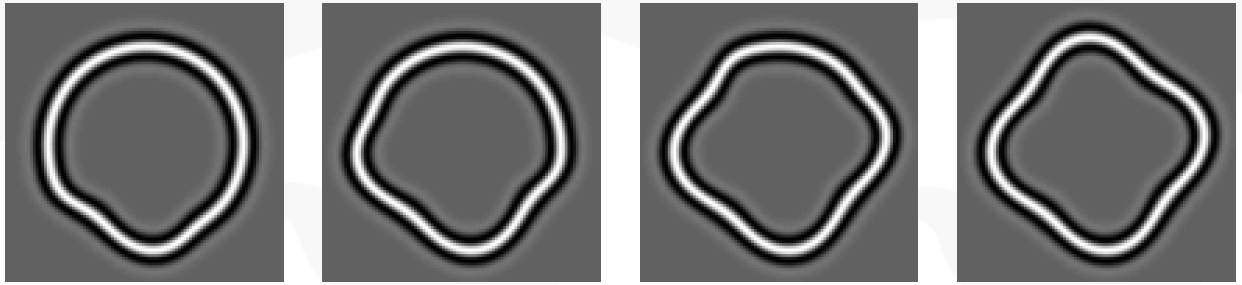
Paradigm



Paradigm

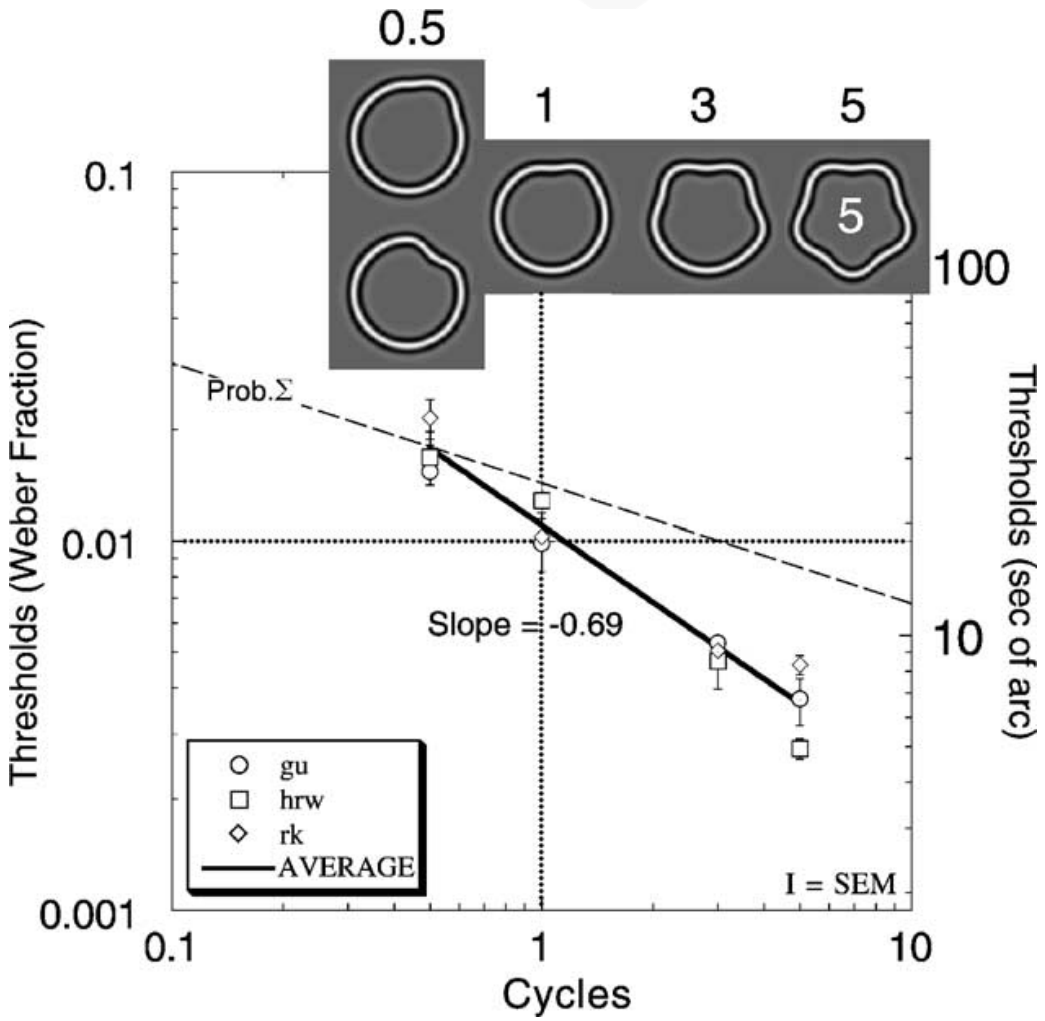


Change in number of modulated cycles



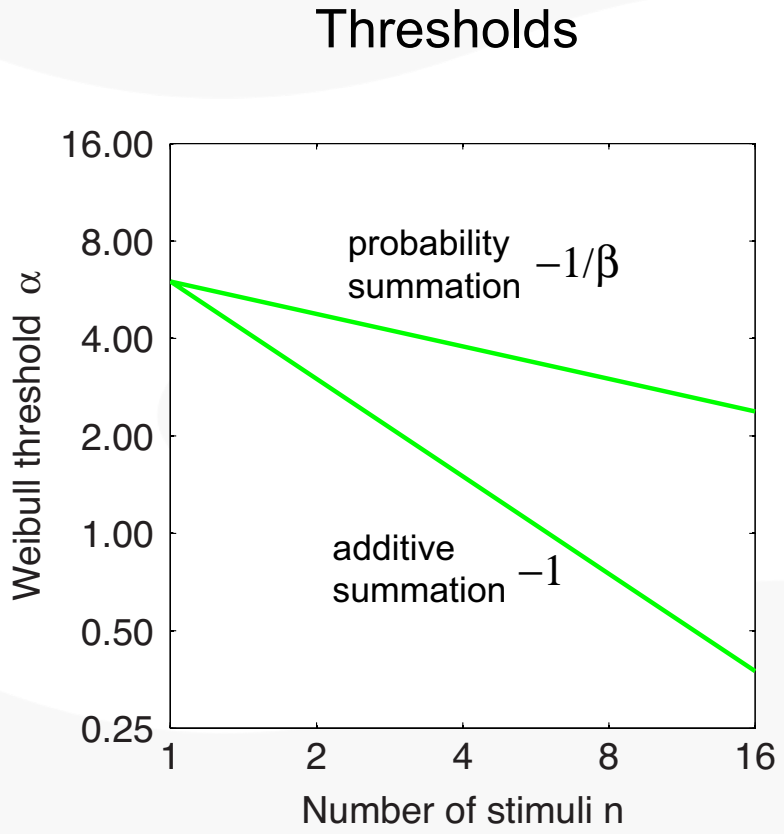
1 2 3 4

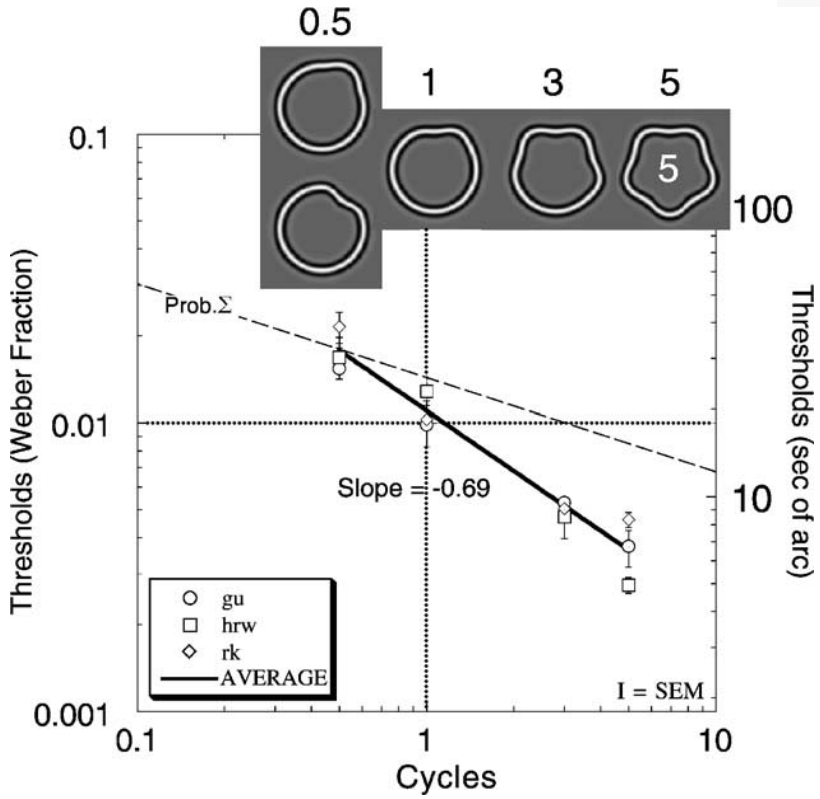
RF summation



Loffler, G., Wilson, H. R., & Wilkinson, F. (2003). Local and global contributions to shape discrimination. *Vision Research*, *43*(5), 519-530.

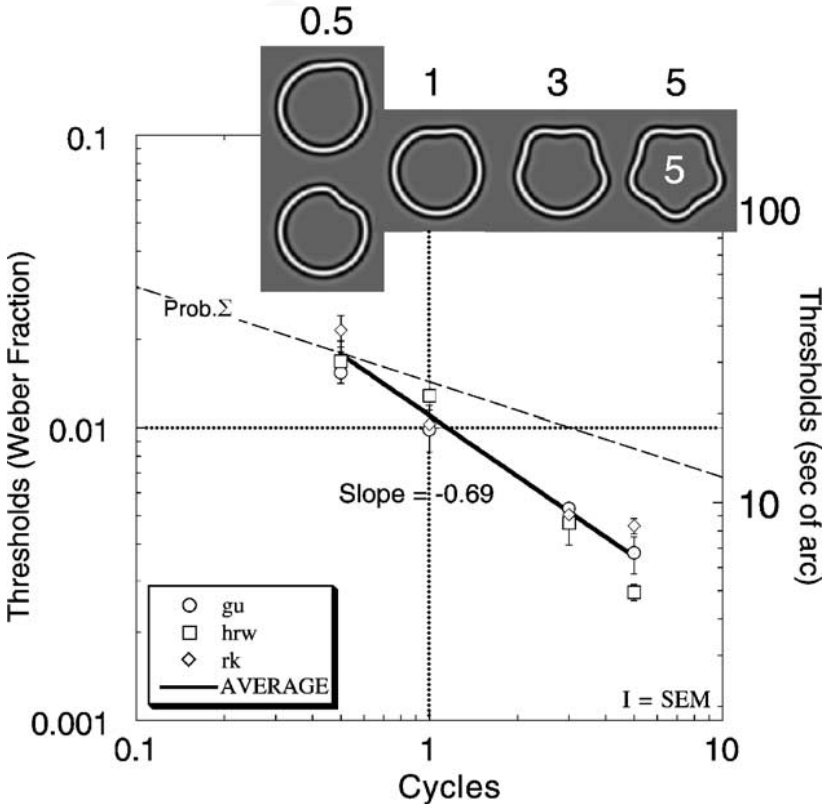
Hight Threshold Theory predictions



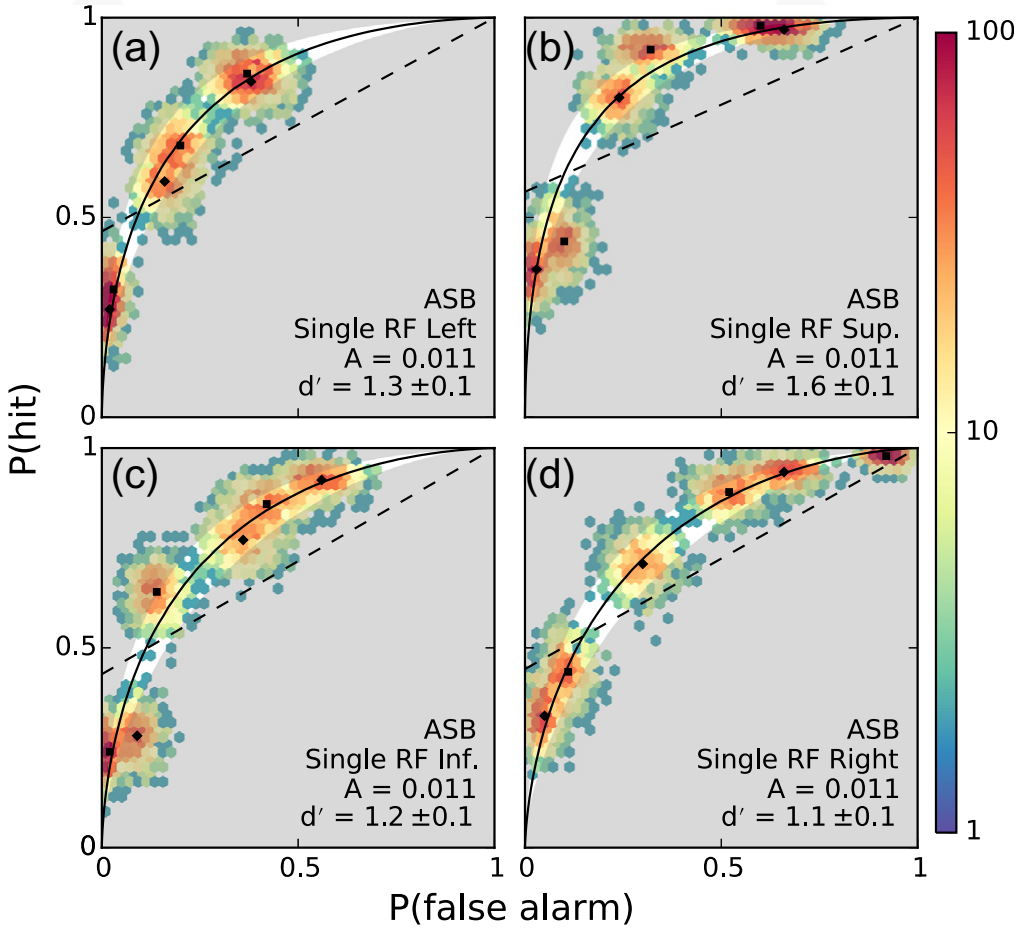


- Summation slopes are typically steeper than that predicted by probability summation (PS) under HTT -> PS rejected
- Under HTT the component mechanisms will be activated if their input exceeds some fixed threshold value
- There is almost no ‘‘penalty’’ under HTT for monitoring additional non-target mechanisms, as any irrelevant internal noise carried by those mechanisms will have a vanishingly small effect on performance

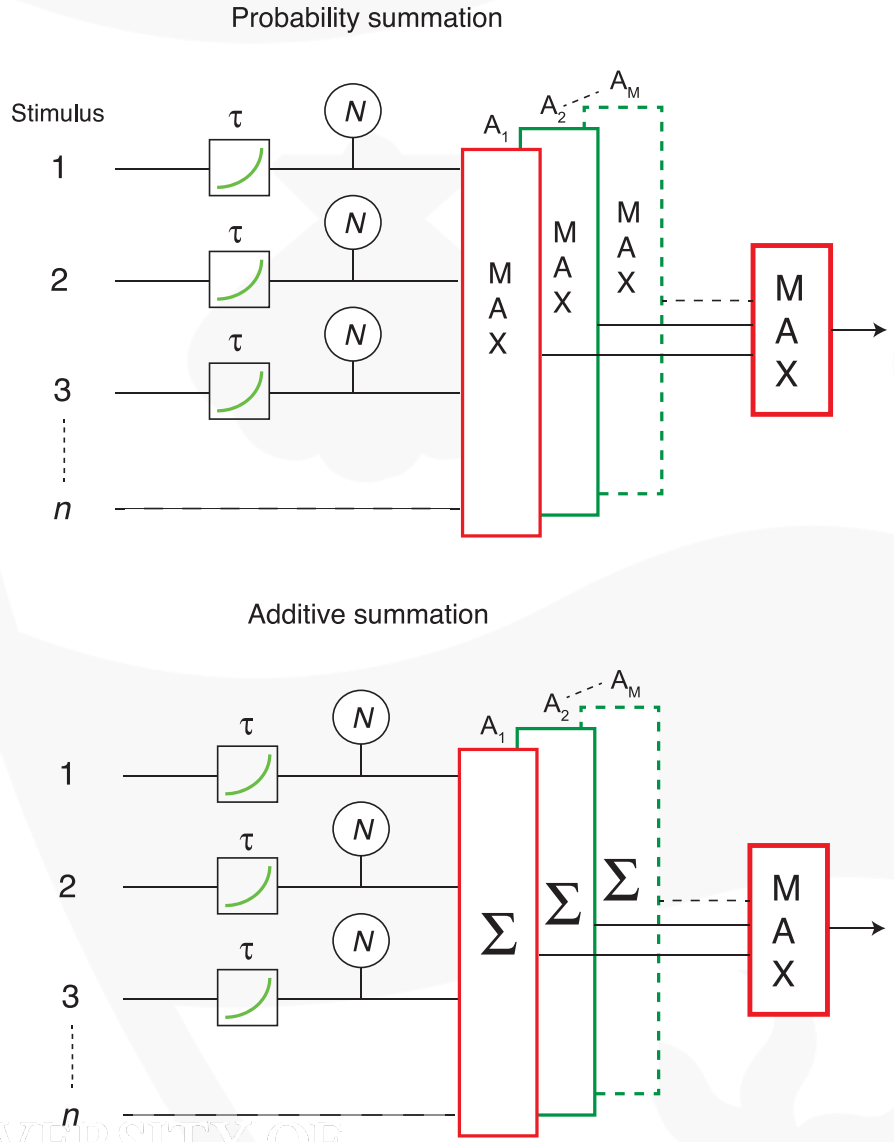
Summation under Signal Detection Theory



Baldwin, A. S., Schmidtmann, G., Kingdom, F. A., & Hess, R. F. (2016). Rejecting probability summation for radial frequency patterns, not so Quick!. *Vision Research*, *122*, 124-134.



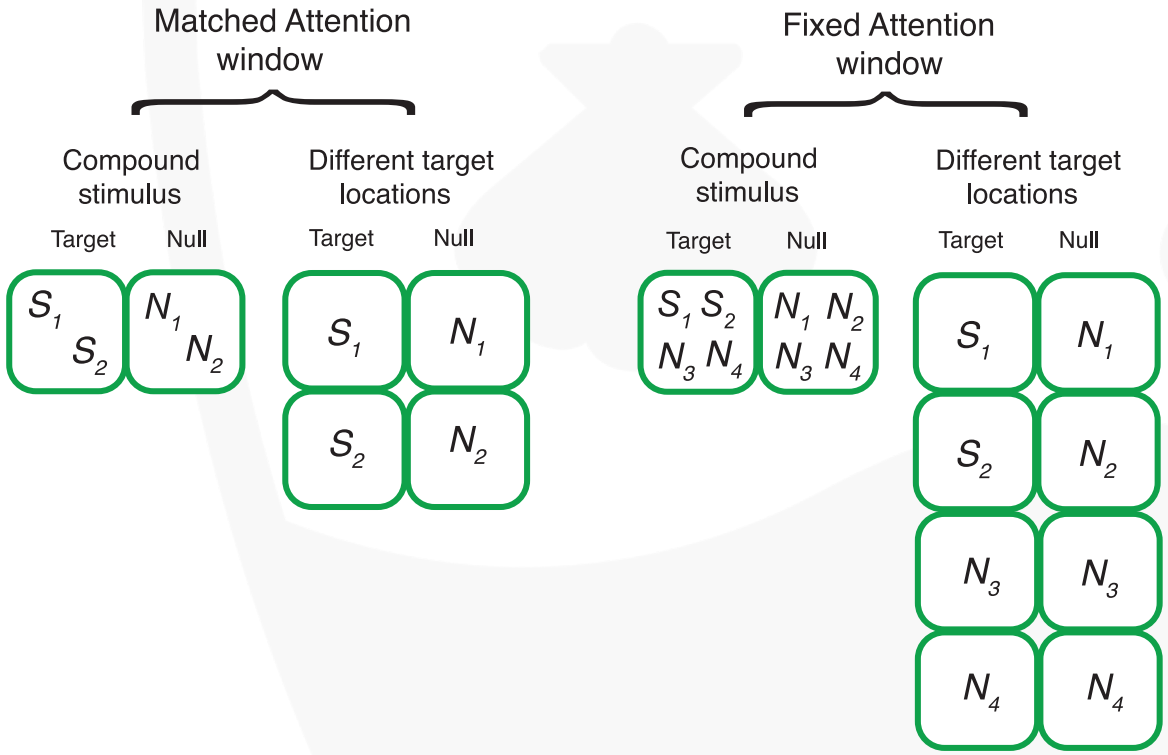
Types of summation



- N = internal noise
- τ = exponent of transducer function
- A_1 = the target alternative / interval
- $A_2 – A_M$ = the non-target (i.e. noise-alone alternatives / intervals)
- M = the total number of alternatives/ intervals in the forced-choice task.
- MAX = MAX decision rule

Kingdom, F.A.A., Baldwin, A. S., & Schmidtmann, G. (2015). Modeling probability and additive summation for detection across multiple mechanisms under the assumptions of signal detection theory. *Journal of vision*, *15*(5), 1-1.

Summation scenarios

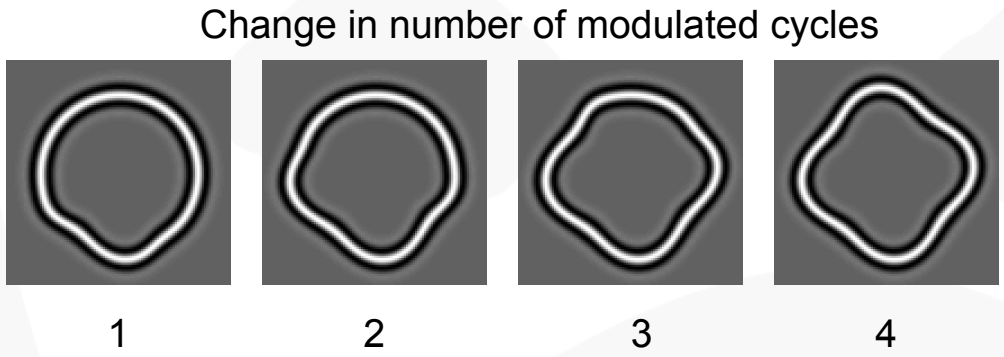


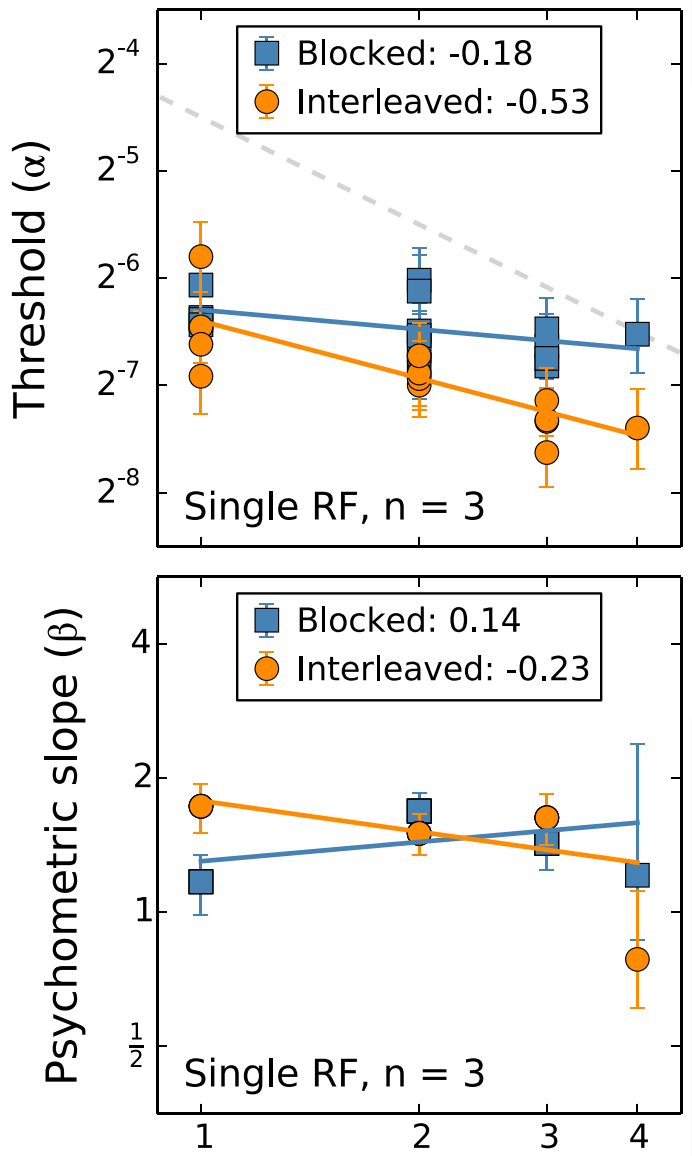
Kingdom, F.A.A., Baldwin, A. S., & Schmidtmann, G. (2015). Modeling probability and additive summation for detection across multiple mechanisms under the assumptions of signal detection theory. *Journal of vision*, *15*(5), 1-1.

- Schematic showing different summation scenarios for a two-interval forced-choice task ($M = 2$) with the target interval containing two stimuli S_1 and S_2
- $N_1 – N_4$ internal noise in the channels/locations sensitive to the stimuli
- Each green box denotes a spatial location
- When the conditions are blocked, the observer can focus attention only on the relevant channels, termed here the ‘‘Matched Attention Window’’ scenario.
- For this situation $n = Q = 2$, where n is the number of stimuli and Q the number of monitored channels/locations
- When the conditions are interleaved, the observer will likely monitor all potentially relevant channels, which means that the observer will also monitor the channels that only contain internal noise. Tyler and Chen (2000) coined the term ‘‘Fixed Attention Window’’ for this scenario. For this situation $n = 2$ and $Q = 4$

Tyler, C. W., & Chen, C. C. (2000). Signal detection theory in the 2AFC paradigm: Attention, channel uncertainty and probability summation. *Vision research*, *40*(22), 3121-3144.

Spatial uncertainty





Baldwin, A. S., Schmidtmann, G., Kingdom, F. A., & Hess, R. F. (2016). Rejecting probability summation for radial frequency patterns, not so Quick!. *Vision Research*, *122*, 124-134.

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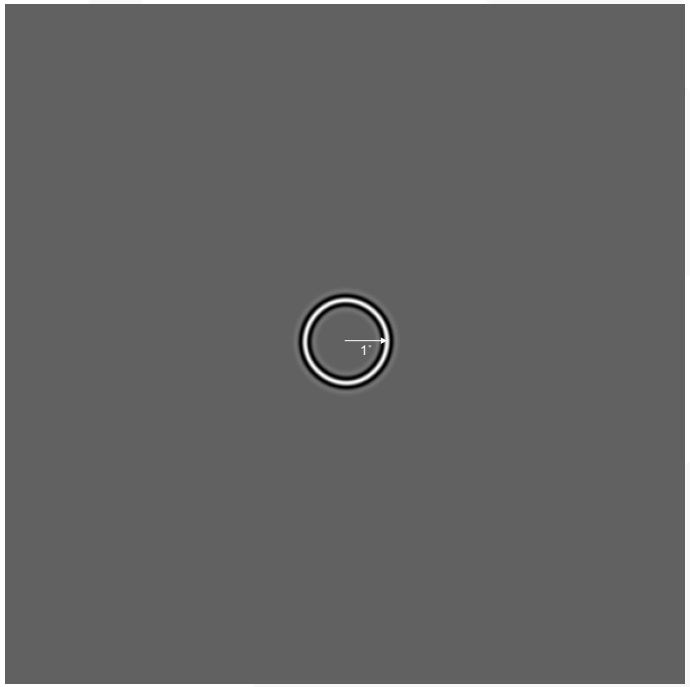
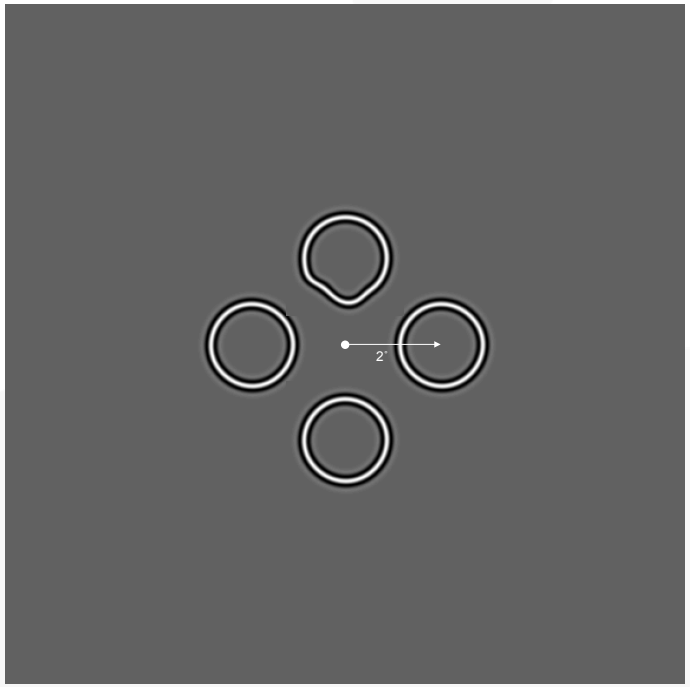
Green, R. J., Dickinson, J. E., & Badcock, D. R. (2018). Integration of shape information occurs around closed contours but not across them. *Journal of vision*, *18*(5),6, 1-13.

Stimuli

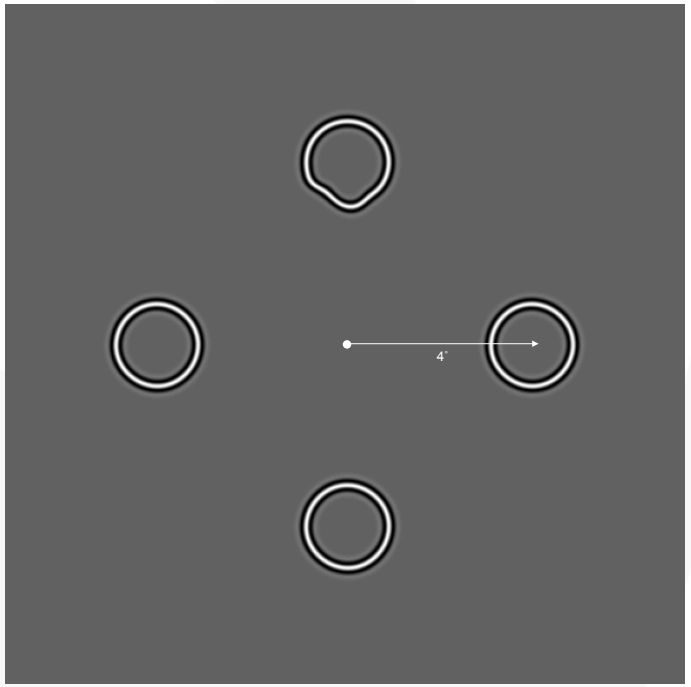
central



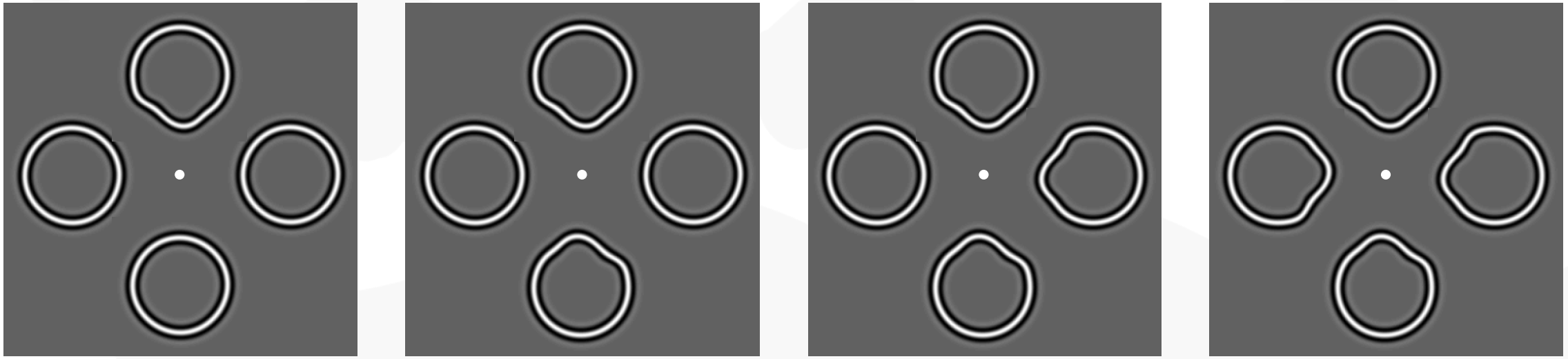
2˚ eccentricity



4˚ eccentricity



Fixed position and blocked (Fixed)

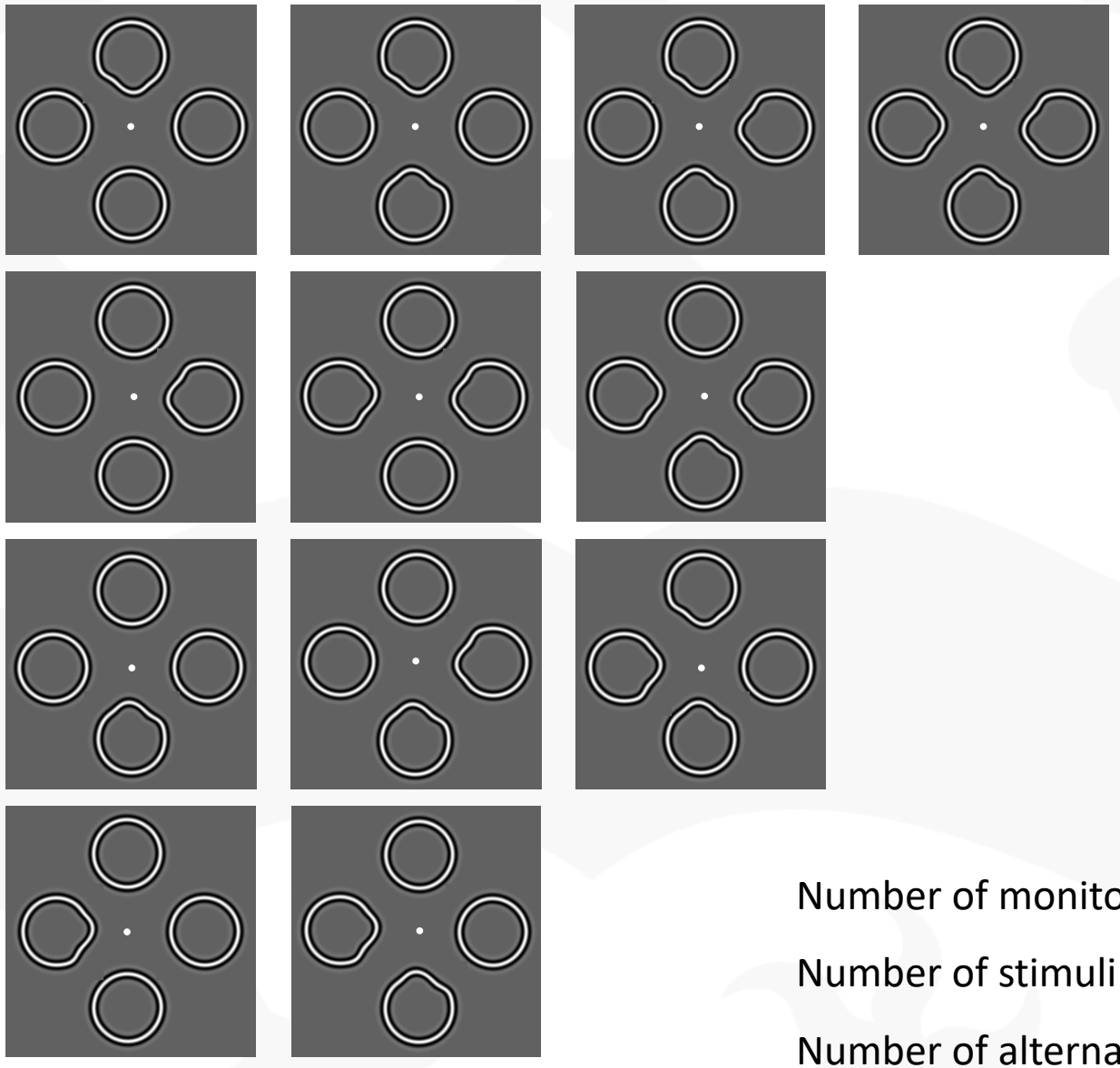


Number of monitored channels: Q = [1 2 3 4]

Number of stimuli: n = [1 2 3 4]

Number of alternatives: M = 2

Variable position and blocked (Semi – Fixed)

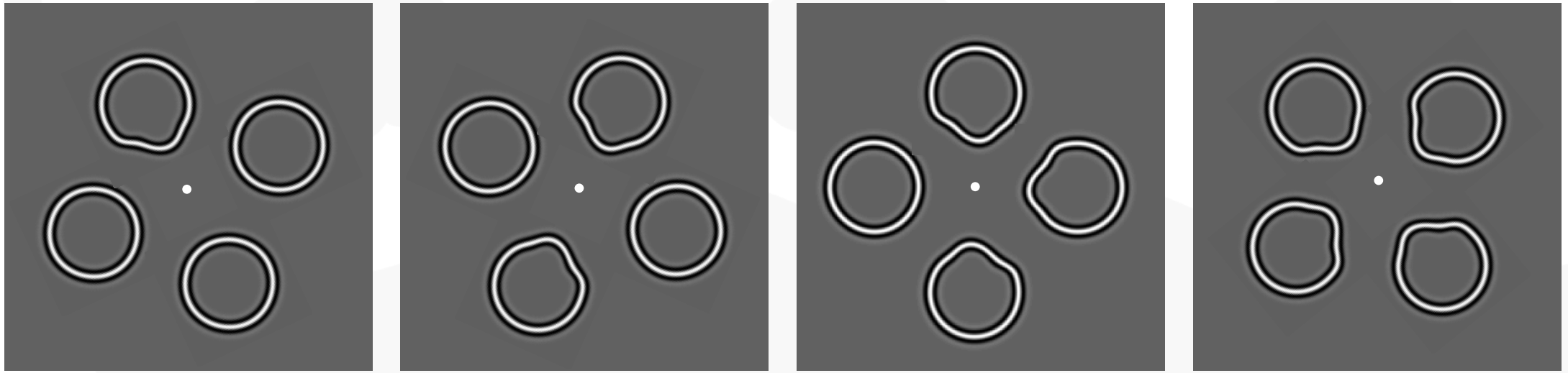


Number of monitored channels: Q = [4 4 4 4]

Number of stimuli: n = [1 2 3 4]

Number of alternatives: M = 2

Random position and interleaved (Random)

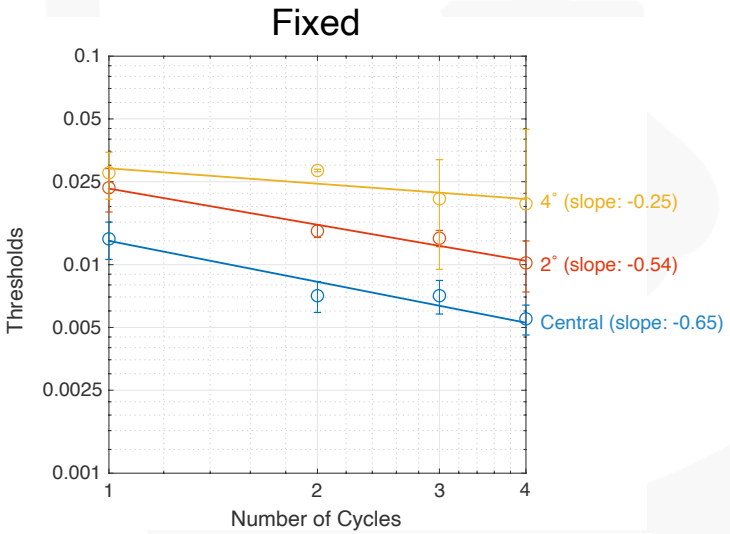


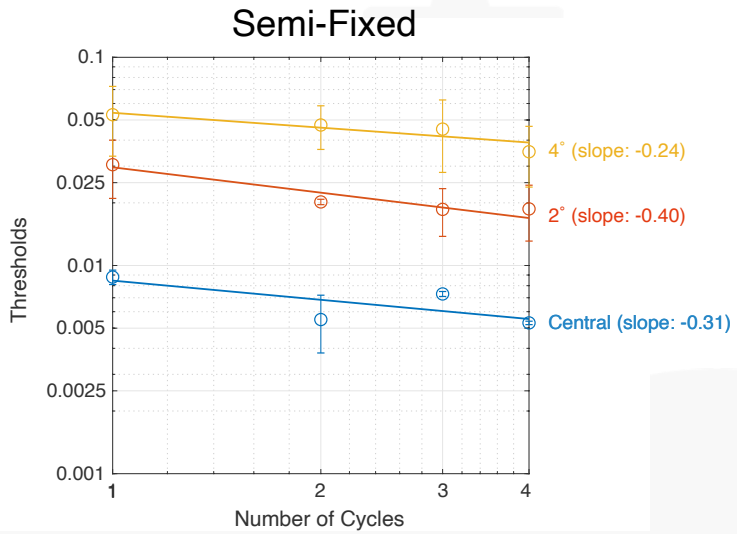
Number of monitored channels: Q = [360 360 360 360]

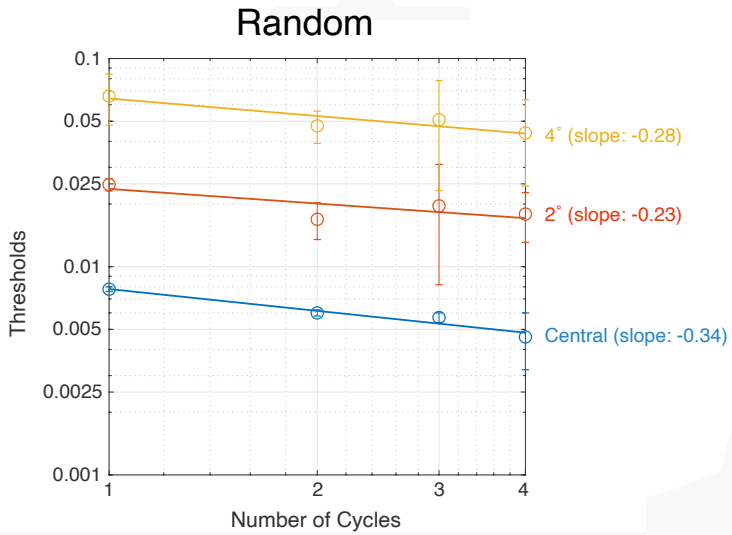
Number of stimuli: n = [1 2 3 4]

Number of alternatives: M = 2

Results - Thresholds







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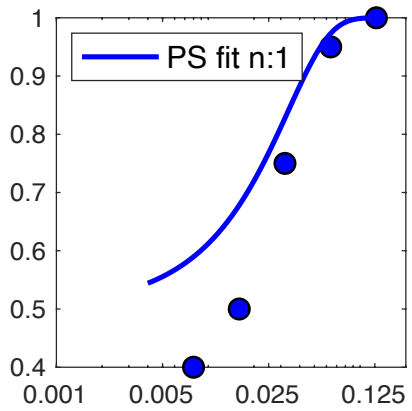
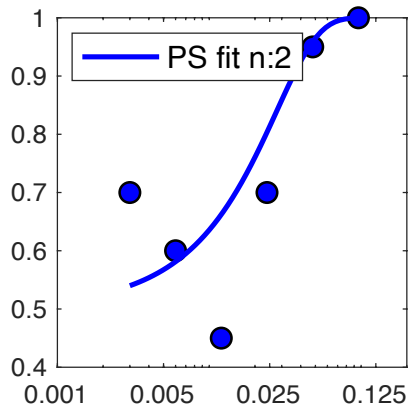
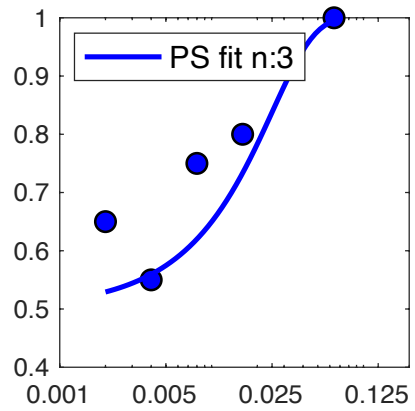
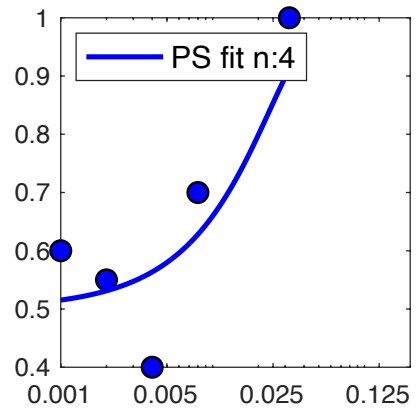
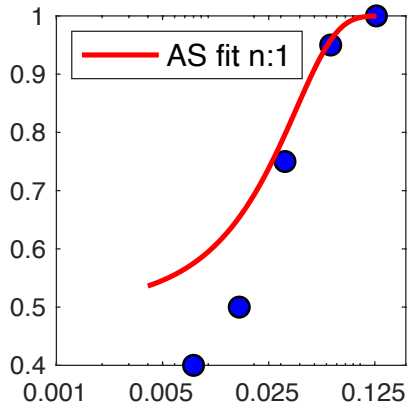
Results – Model simulations

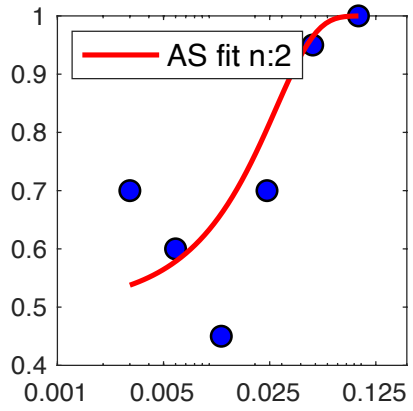


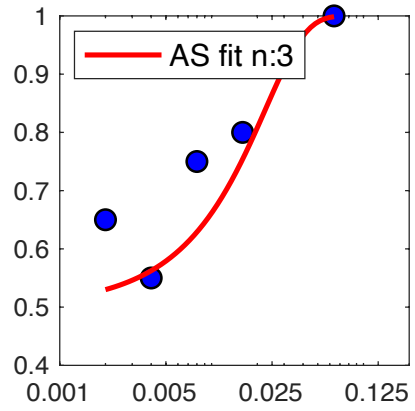


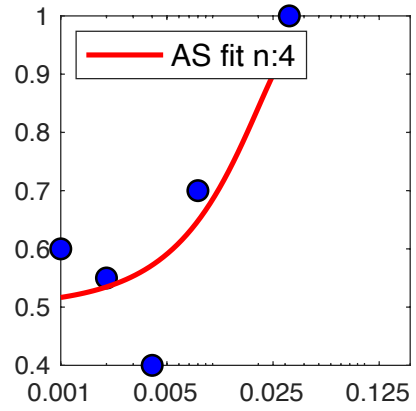




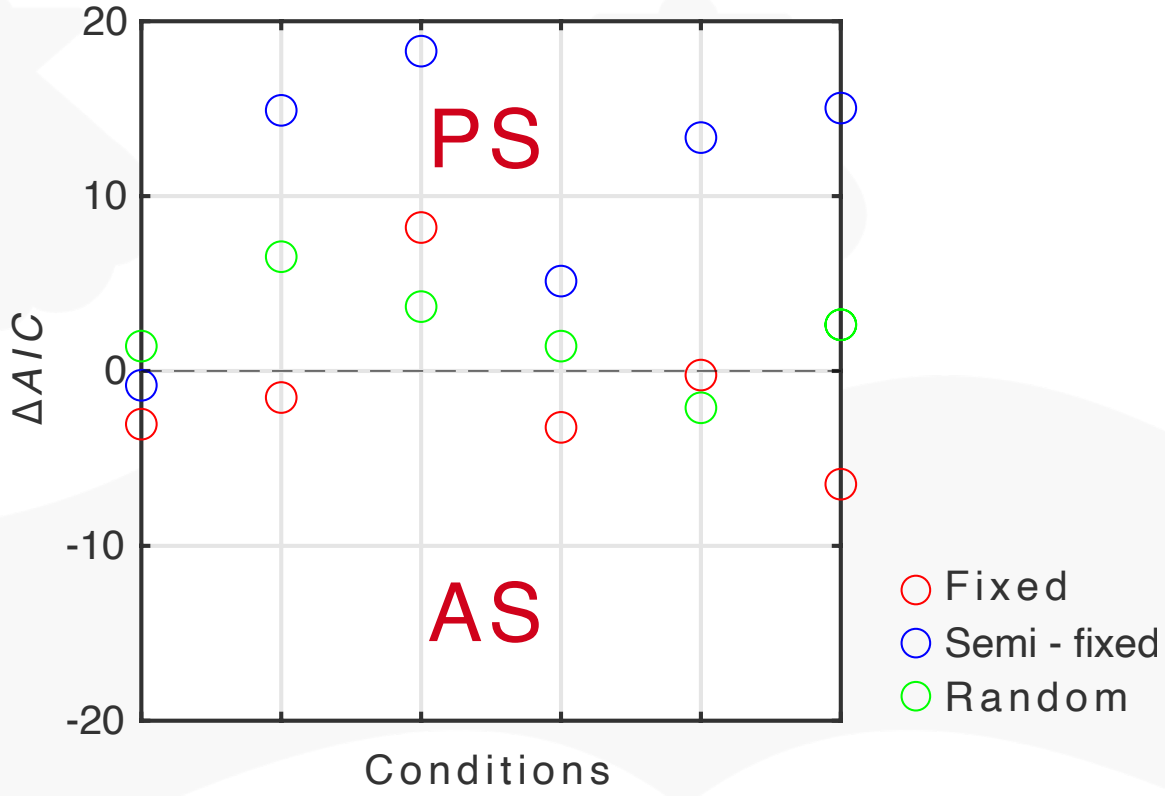








Results - Models

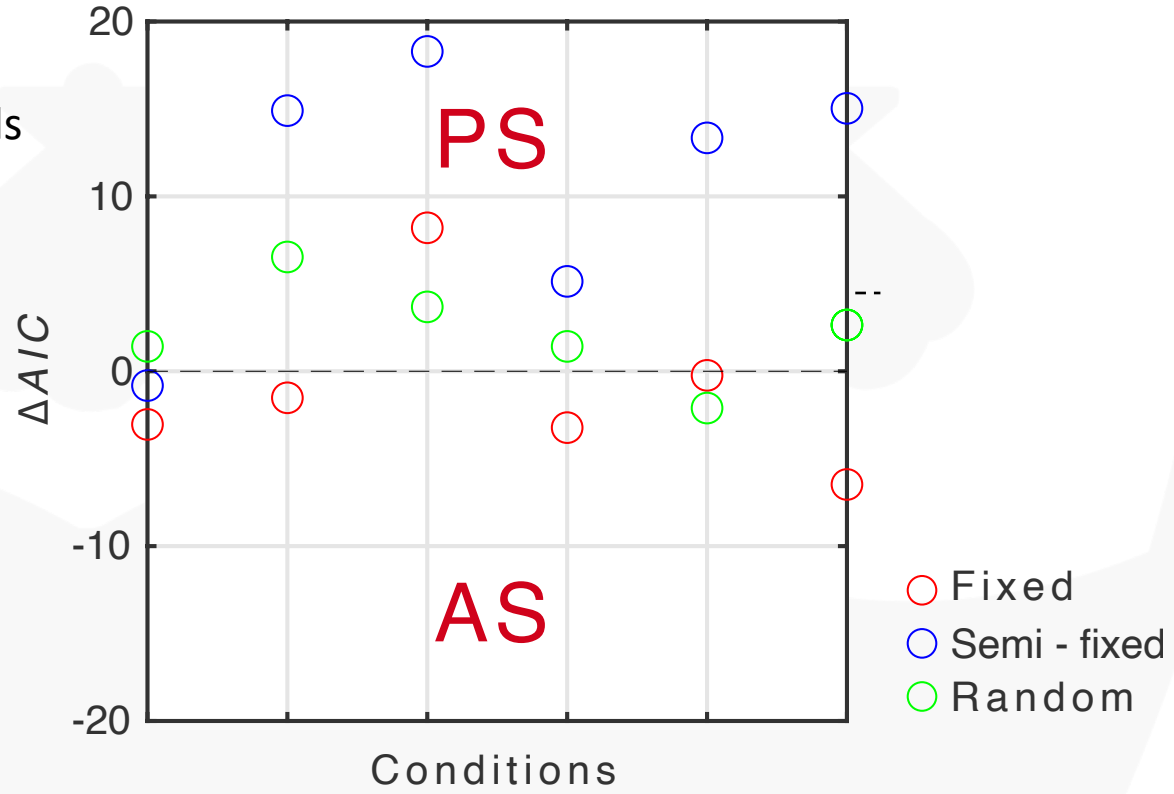


Results - Models

- The model with the smallest *AIC* values is the probability summation model
- The differences in *AIC* values between the PS and AS models are relatively small
- According to Burnham and Anderson (2004), the preferred model can be determined by calculating the difference between the AIC scores of the *i-th* model (AIC_i) and the model with the lowest AIC score (AIC_{min}) obtained from the set of models examined

$$\Delta_i = AIC_i - AIC_{min}$$

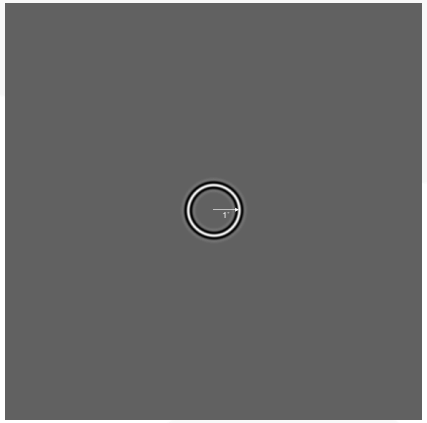
- Models with $\Delta i > 7$ can be rejected (Burnham & Anderson, 2004)

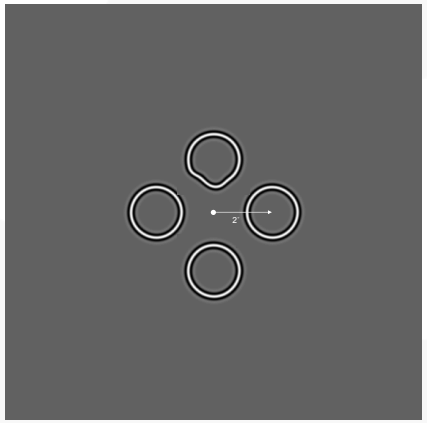


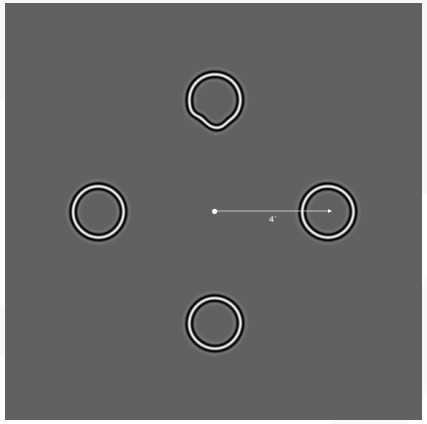
Burnham, K. P., & Anderson, D. R. (2004). Multimodel inference: understanding AIC and BIC in model selection. *Sociological methods & research*, *33*(2), 261-304.

Discussion

- We can not reject PS as a model
- In agreement with Baldwin et al. (2016)
- Summation is similar whether it occurs within a single shape or across shapes
- In agreement with Baldwin et al. (2016)
- Independent of eccentricity
- Largely independent of uncertainty (*cf.* Green et al., 2017, 2018)
- This implies that the visual system does not treat single closed shapes any different from various shapes distributed across the visual field.







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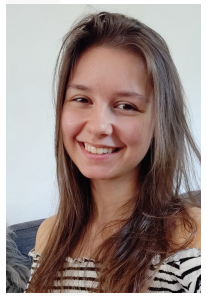

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