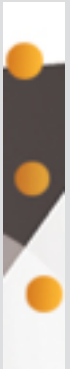


PLAsticiTY of P erceptual space U nder S ensorimotor interactions



**Research and Innovation
Staff Exchange (RISE) Call:
H2020-MSCA-RISE-2016**



A gap in the map: the blind spot

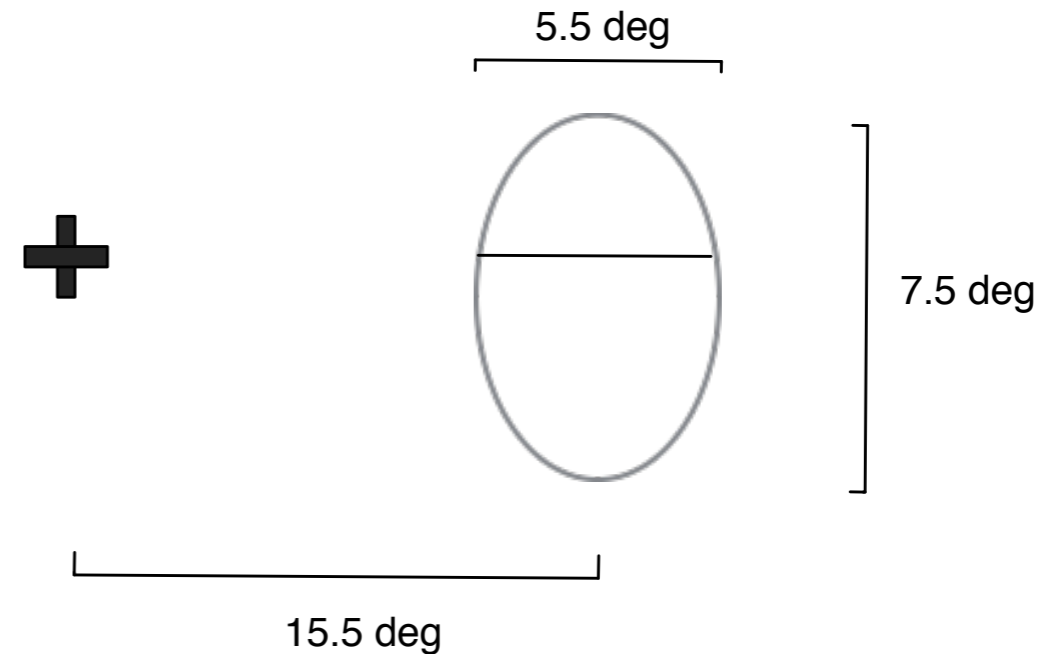
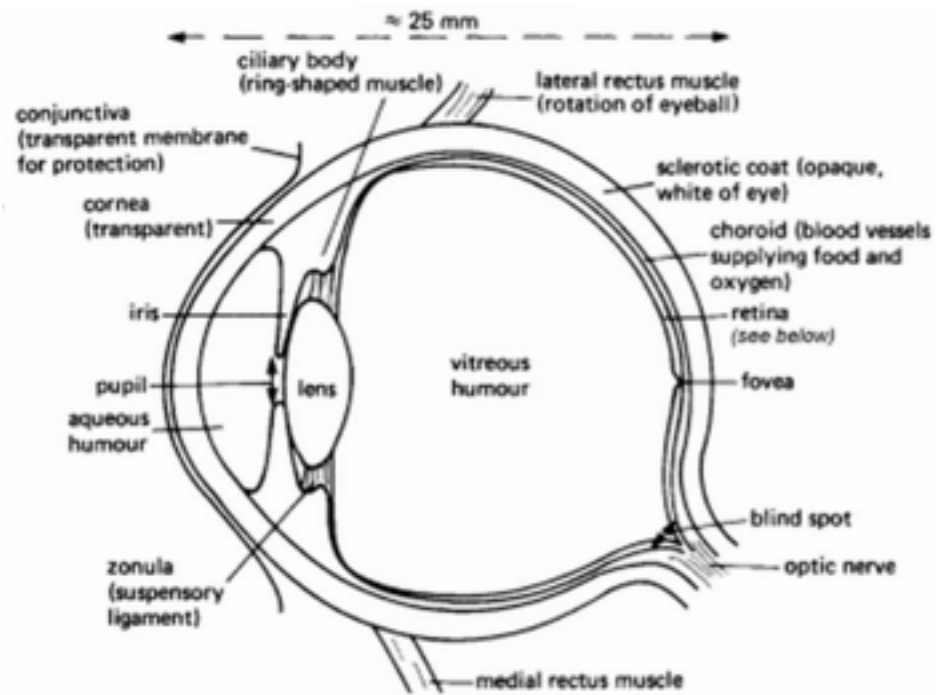
Task 2.1



Task 2.1

...**First precise measurements of the edges of the blind spot** in the human eye will be undertaken using the highly controlled setup for fixational eye movements at BU in cooperation with WWU and UMR (Task 2.1). We will study the transition between the blind spot and the adjacent recipient part of the retina in detail in order to **determine the contribution of this transitional region to filling-in....**

Summary of the literature

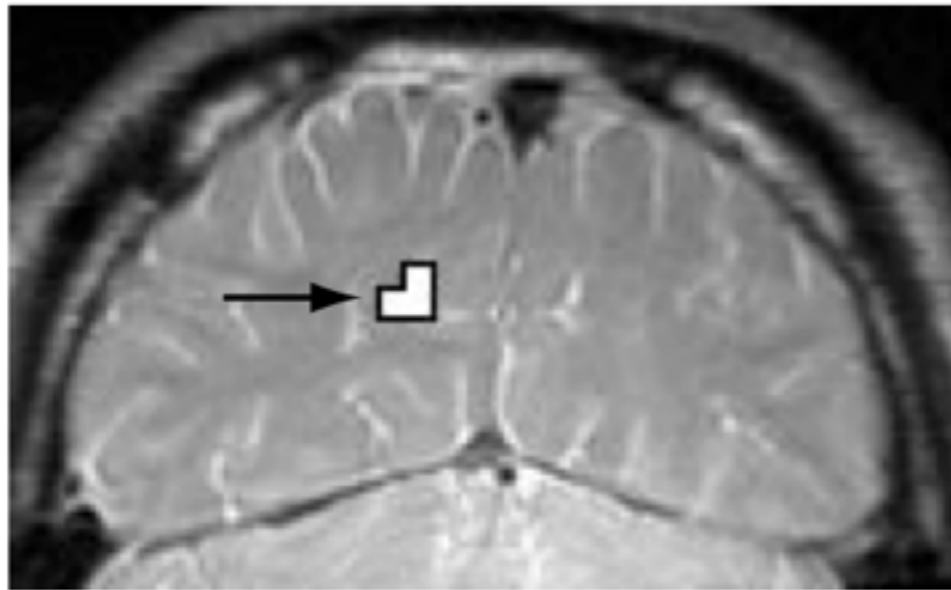


very heterogenous results -
depend on:
stimulus size
stimulus contrast
and way of measurement

	width	height
Dolderer et al.(2006)	4-5	4-5
Armaly (1969)	7.5	10
Safran (1993)	7.0	9.2
Harrington (1976)	5.5	7.5
Chamlin (1960)	6.87	7.4
Traquair (1948)	5.5	7.7

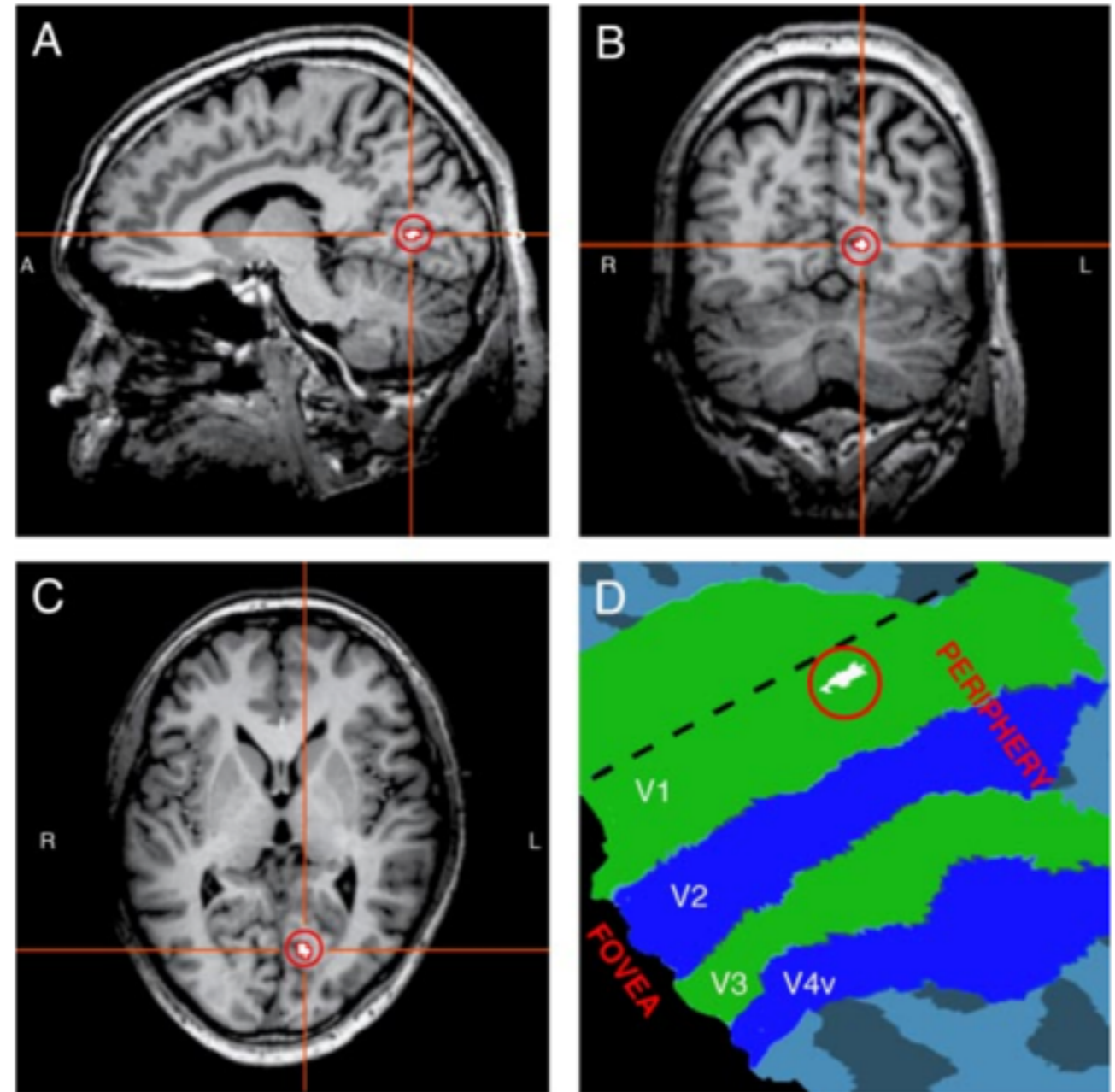
Neurophysiological underpinnings

c



Representation of blind spot in V1 figure from Tong and Engel (2001)

Cortical region corresponding to the anatomical and functional blind spot lies anterior to the occipital pole in V1 (Awater et al., 2005; Tong and Engel 2001; Tootell et al., 1998)



Representation of blind spot in V1 figure from Awater et al. (2005)

Characteristics of the blind spot

- Blind spot has a representation in V1 (*monkey: Azzi et al. 2015; human: Awater et al., 2005*), i.e. there are receptive fields in the V1 map that represent the space of the blind spot in the retinal image
- Large and discontinuous receptive fields for neurons in V1 probably responsible for completion process (*Fiorani et al., 1992; Komatsu et al. 2000,2002; Komatsu, 2006; Matsumoto & Komatsu, 2005*)
- Size of the blind spot varies between subjects, borders are irregular. Minimal stimulation area surrounding the blind spot to achieve filling in needs to be 0.05 deg wide (*Spillmann et al., 2006*)
- Nasal slope is steeper than temporal slope (*Safran et al., 1993*)
- Visual field is not distorted around the blind spot (*Tripathy et al., 1996; Awater et al., 2005*)

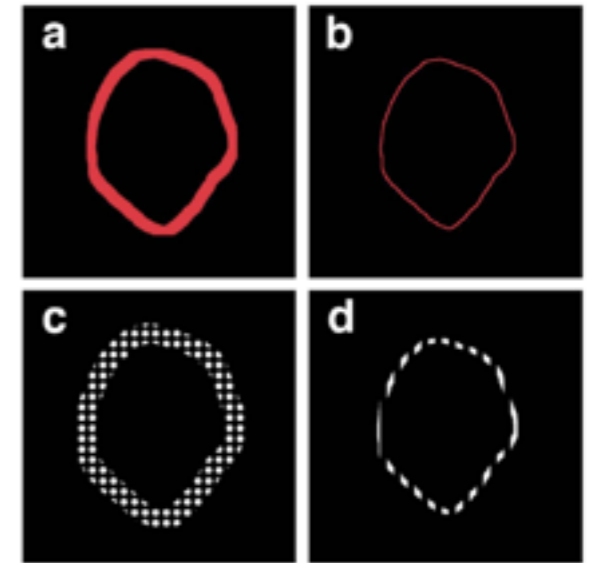


figure from Spillmann et al. (2006)

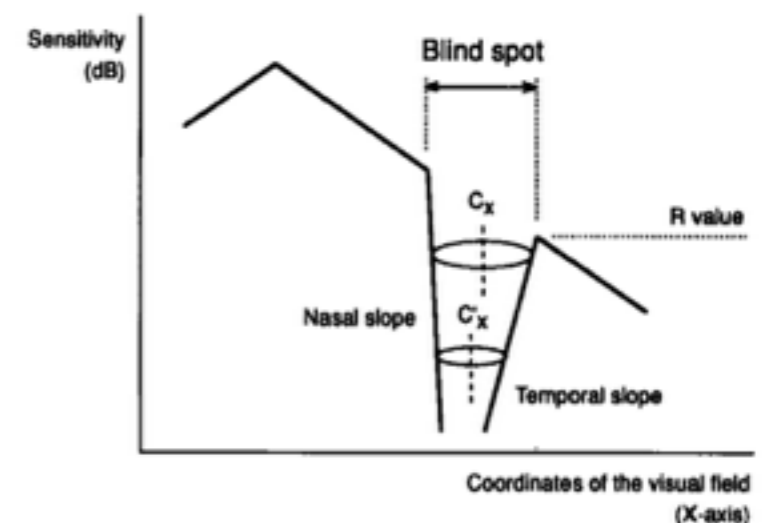


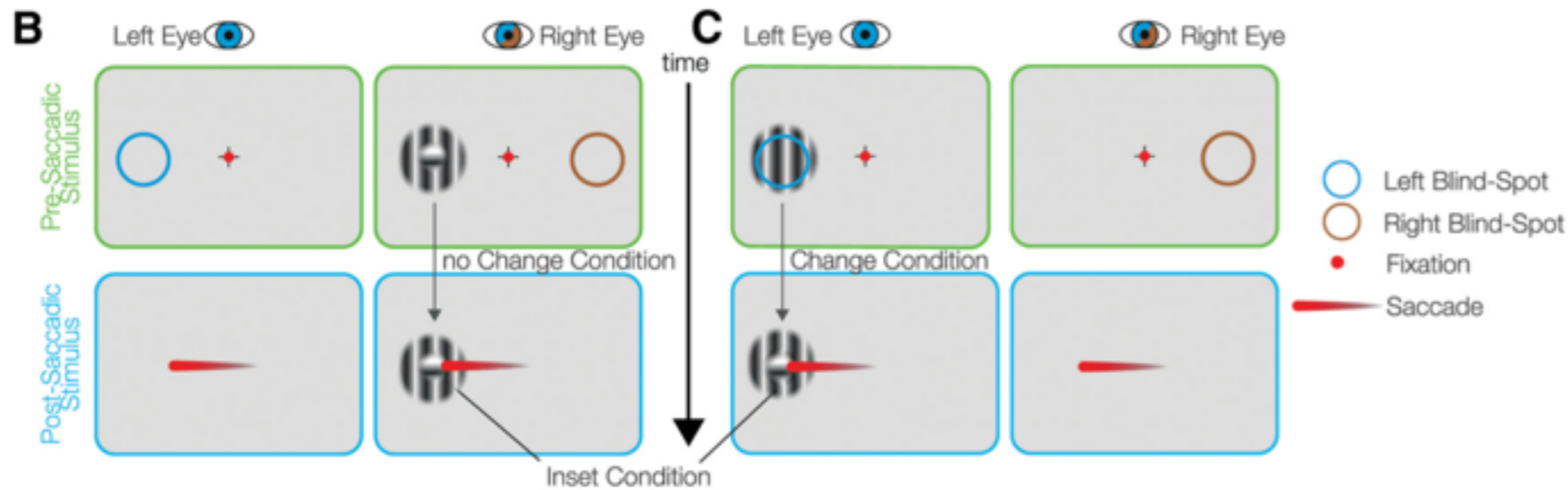
figure from Safran et al. (1993)



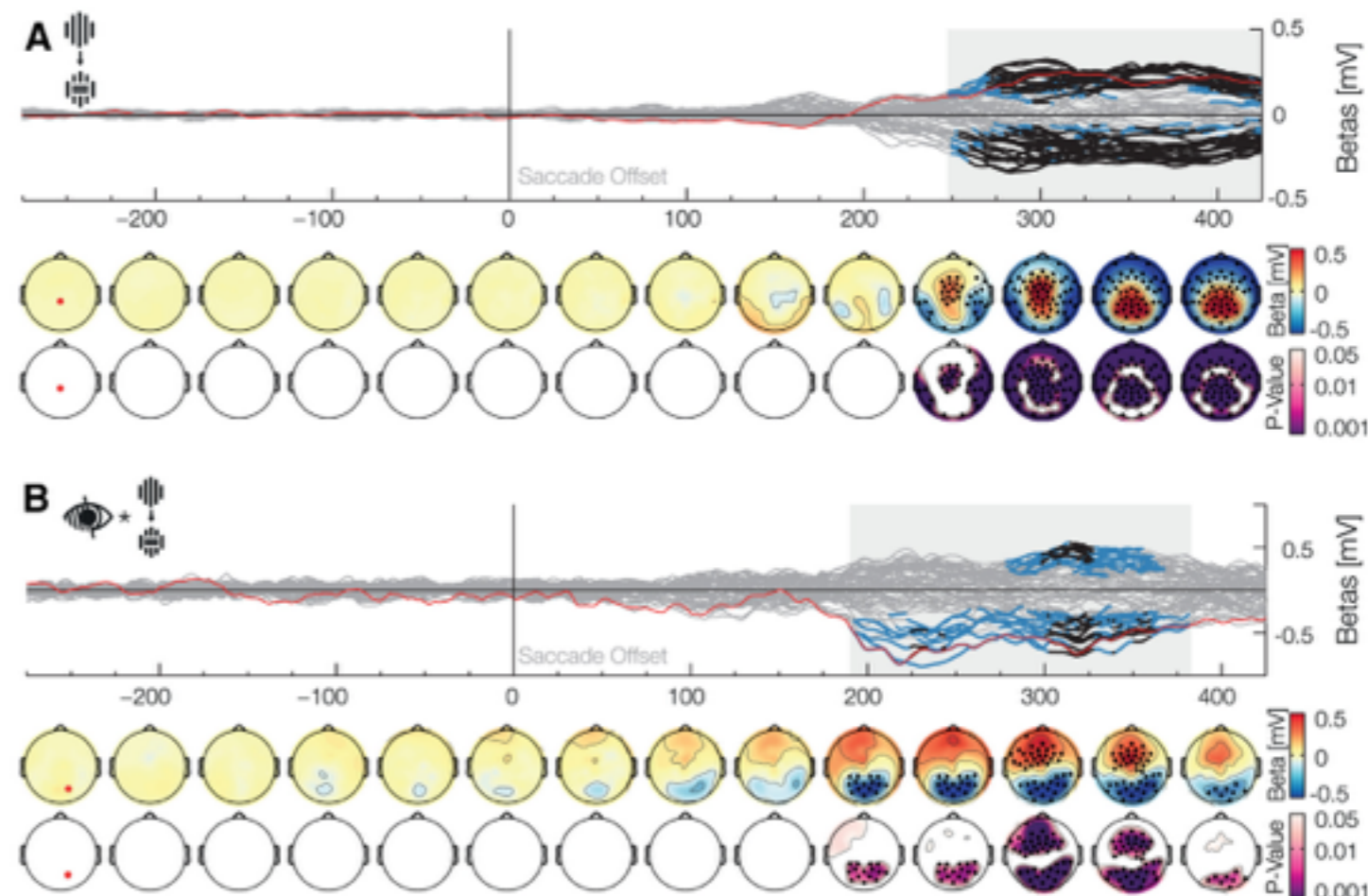
How functionally blind is the blind spot?

- Filling-in works either by lateral propagation (8 mm) or feedforward connections (up to V2, then feedback into V1) (*Azzi et al., 2015; Matsumoto & Komatsu, 2005*)
- Stimulation of the blind spot in one eye can induce motion after-effects in the fellow eye (*Murakami, 1995*)
- Filled-in grating can induce binocular rivalry in the fellow eye (*Tong & Engel, 2001*)
- Motion extrapolation into the blind spot (*Maus et al., 2008, Maus et al., 2016*)

How functionally blind is the blind spot?

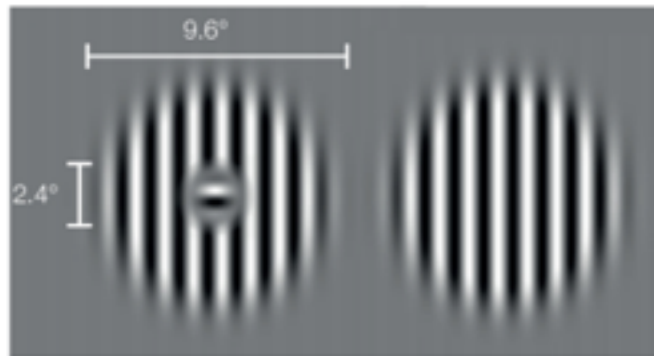


Predictions of Visual Content across Eye Movements and Their Modulation by Inferred Information (Ehinger B., König P., Ossadon J., 2015)



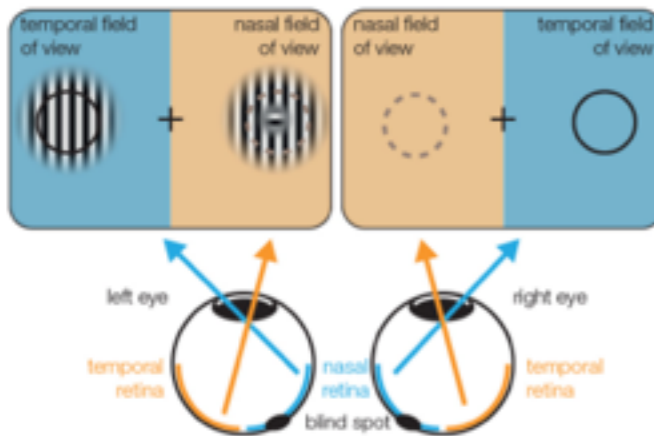
How functionally blind is the blind spot?

a



Humans treat unreliable filled-in percepts as more real than veridical ones. (Ehinger, B. V., Häusser, K., Ossandón, J. P., & König, P., 2017)

c



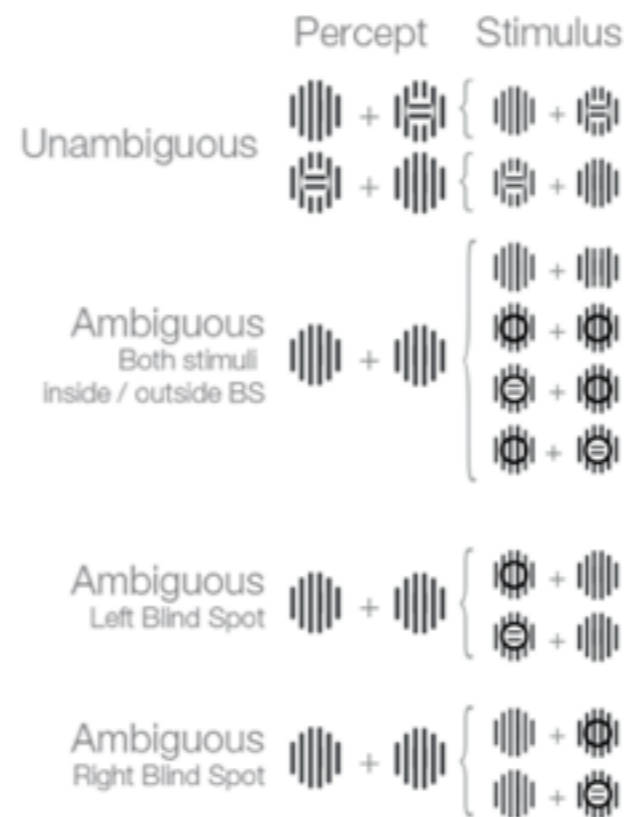
Stimulation



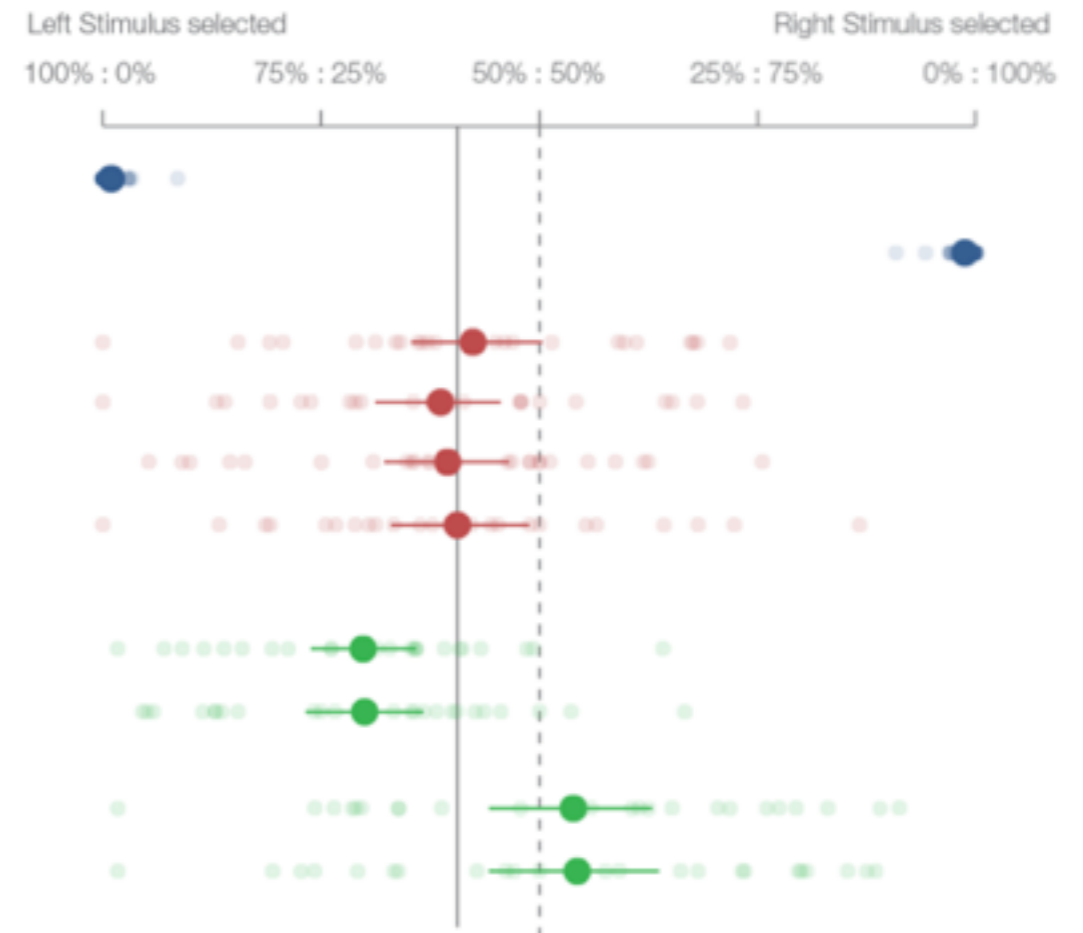
Percept



a



Which stimulus is continuous?



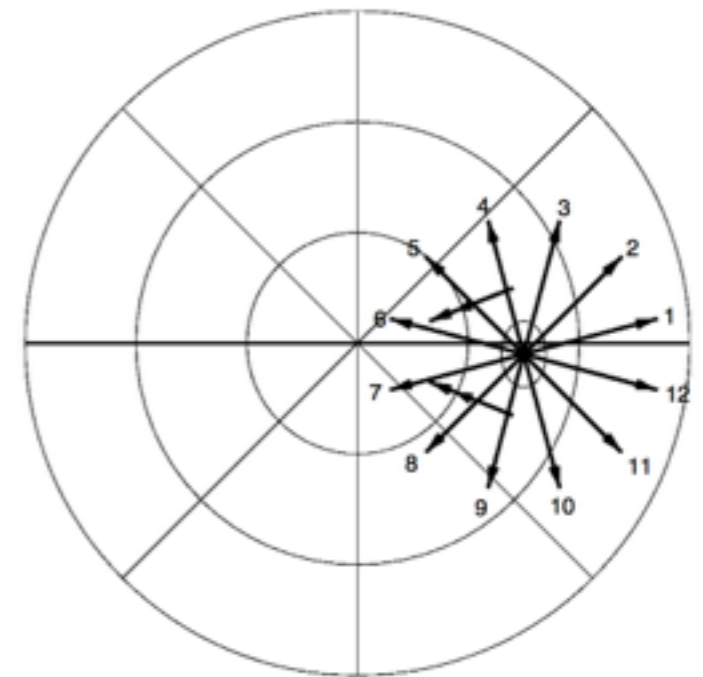
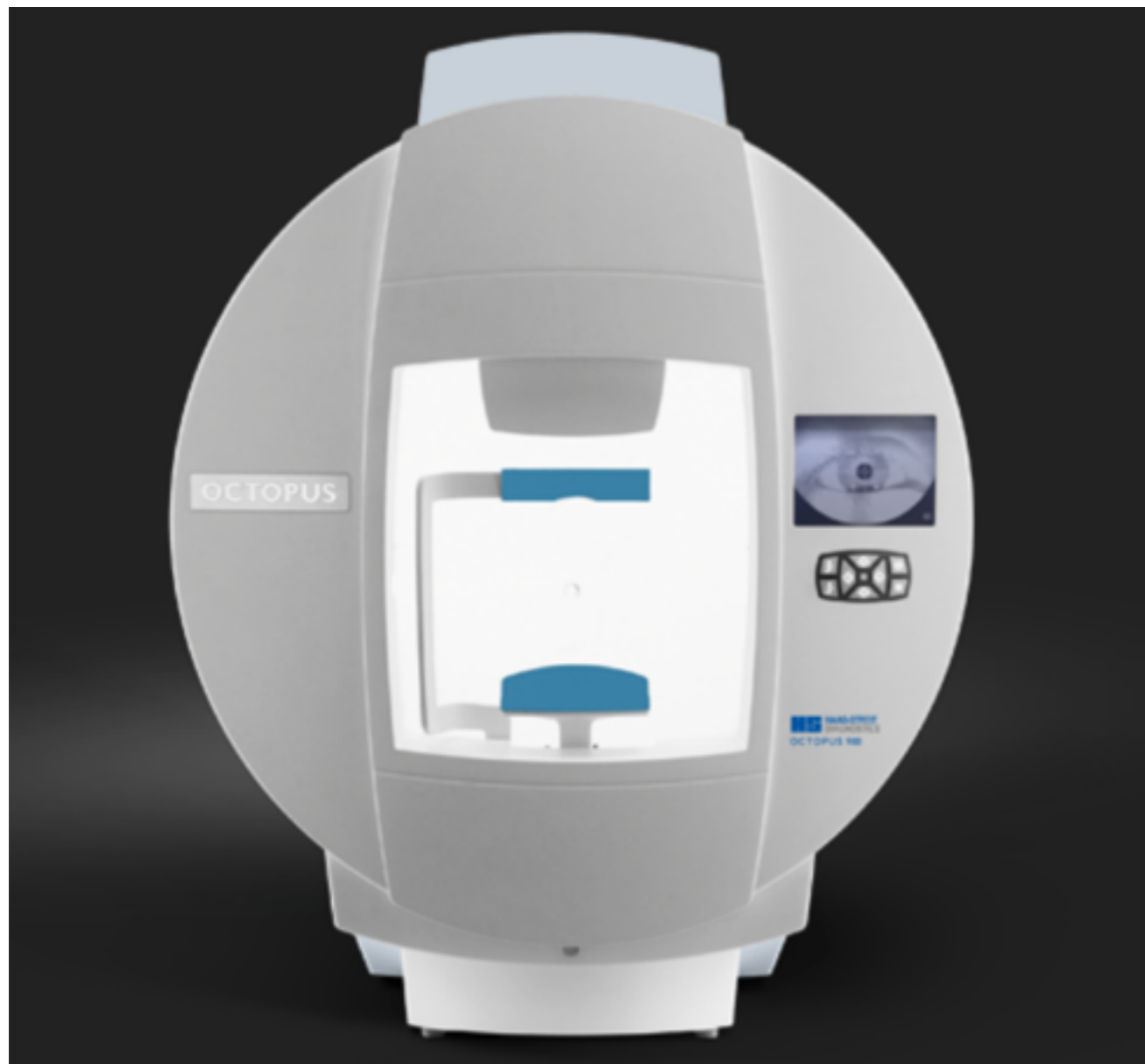


Measurement of the blind spot

- by ophthalmologists in clinical and normative studies
- by neuroscientists that use the blind spot as a tool (region of no retinal input)

Optometry

- Measurement with a perimeter



Dolderer et al., (2006)
Measurement with perimeter CTT
probably similar with Octopus900

Determining the blind spot in functional studies

1) The subject moves a small stimulus (flickering circle /red cross) around the border of the blind spot and clicks when it is just inside the blind spot.

(Spillmann et al., 2006; Maus et al., 2016; Maus and Nijhawan, 2008, Chen et al., 2017)

2) The subject adjusts a disc (flickering /filled red) as big as possible at the location of the blind spot *(Ehinger et al. 2015, 2017; Qian, 2017)*

3) In Baek *(2012)* a point moves at a constant speed through the blind spot. Subject presses button when the point disappears.

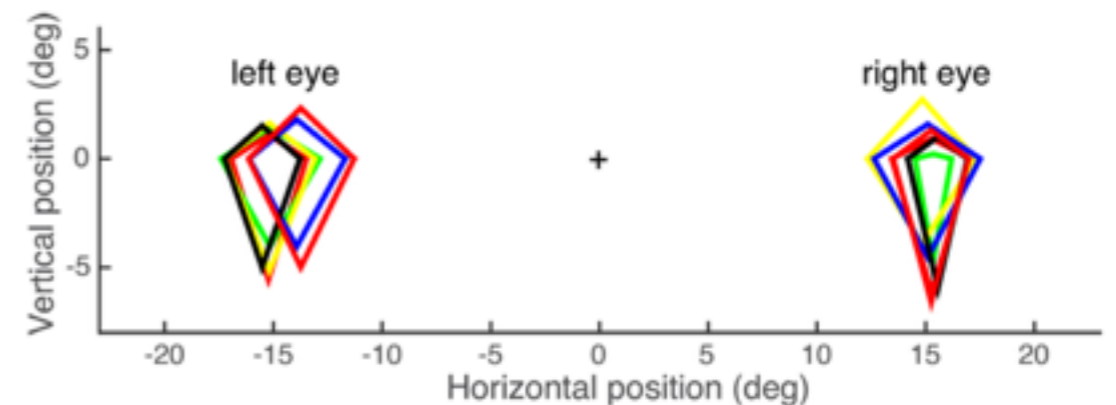


figure from Maus et al. (2016)



How to map the blind spot border

- avoid predictions (randomized positions of stimuli)
- gaze contingent display of the stimulus
- stationary stimuli (preferably small, short presentation times)
- inner border of blind spot is at ~ 12 deg, working with LED panel might be necessary



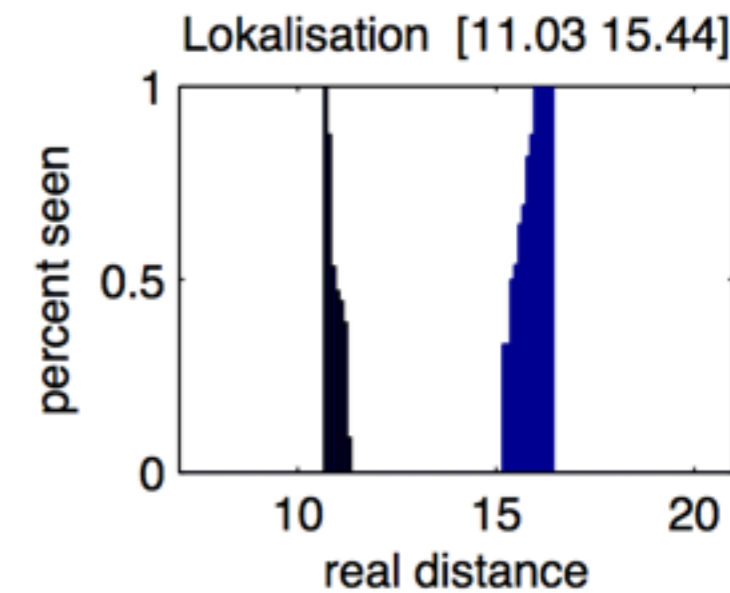
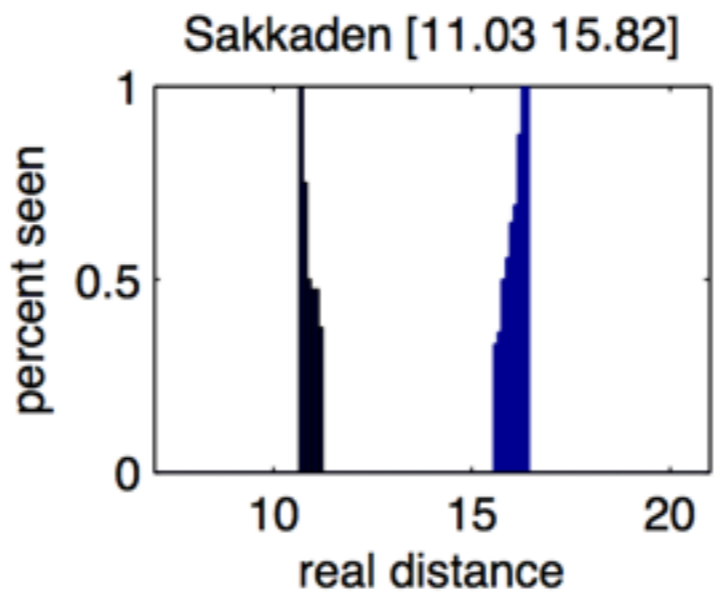
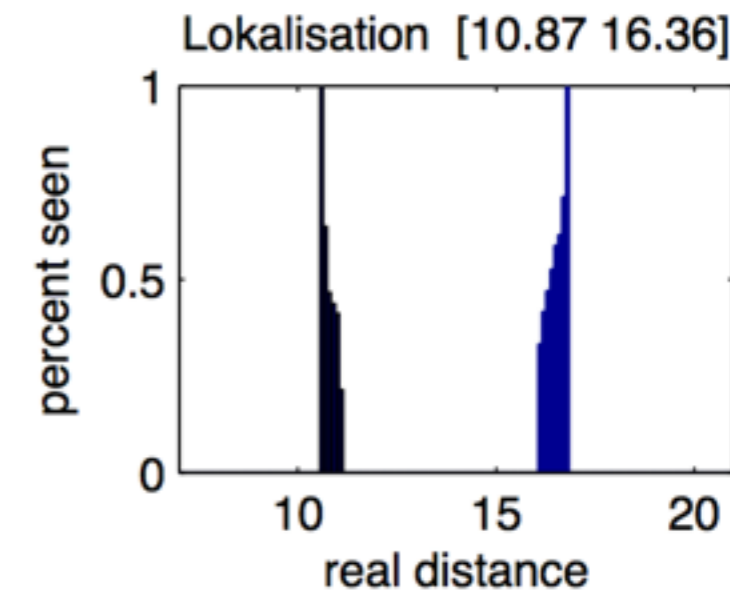
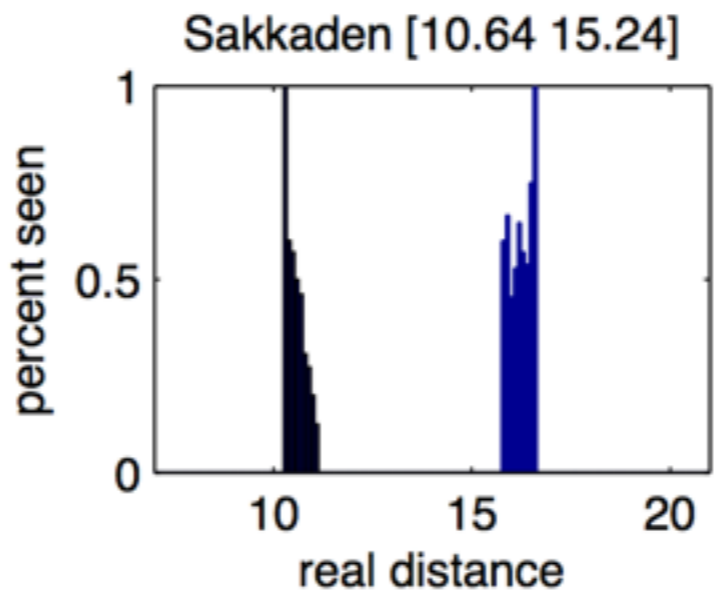
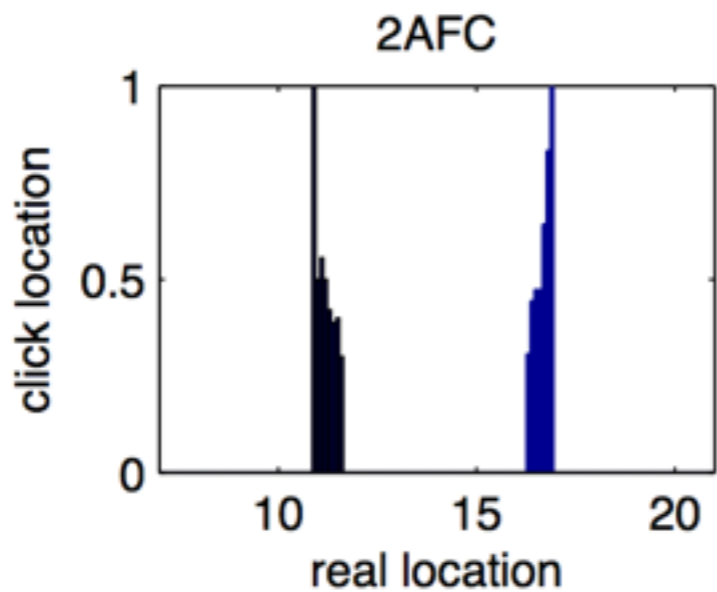
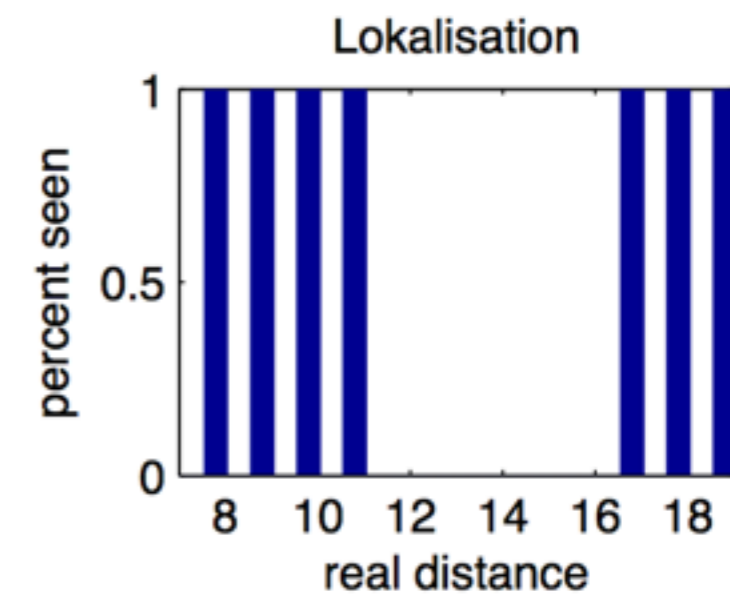
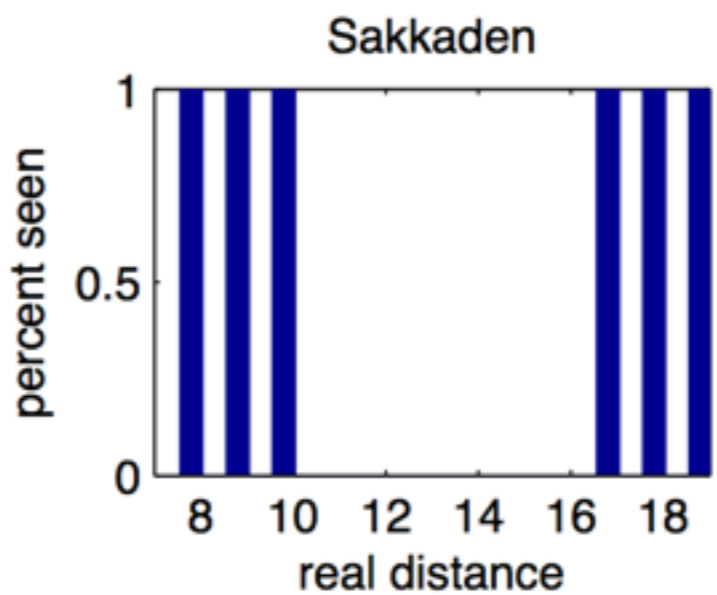
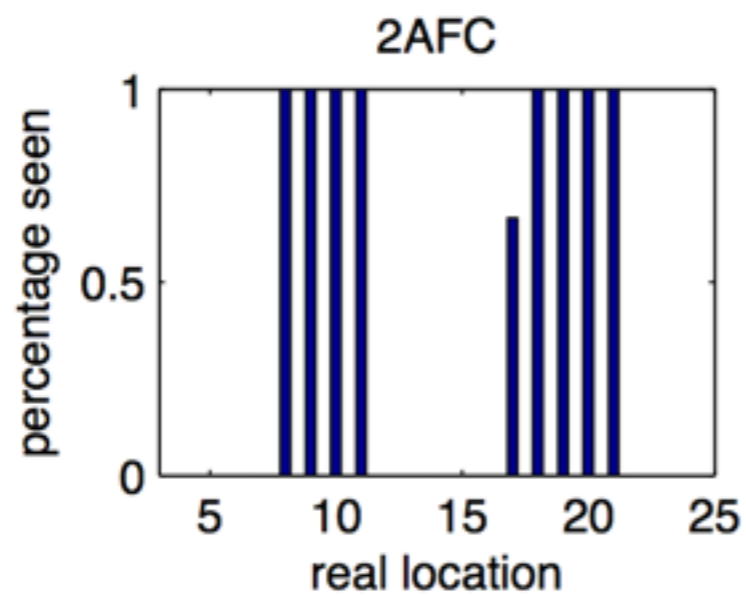
Preliminary data

- Eyelink 1000
- gaze contingent display of the target
- black target ($1.5\text{deg} \times .3\text{deg}$) background [170 170 170], flashed for 1 frame (17 ms) or 200 ms at meridian
- 3 types of answering: 2 AFC, saccade to target, localize target by mouseclick

Subject 1

17 ms

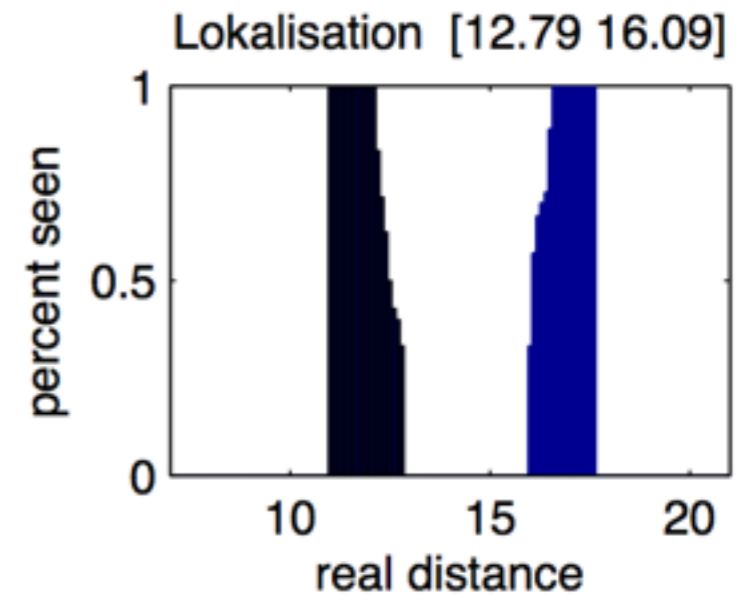
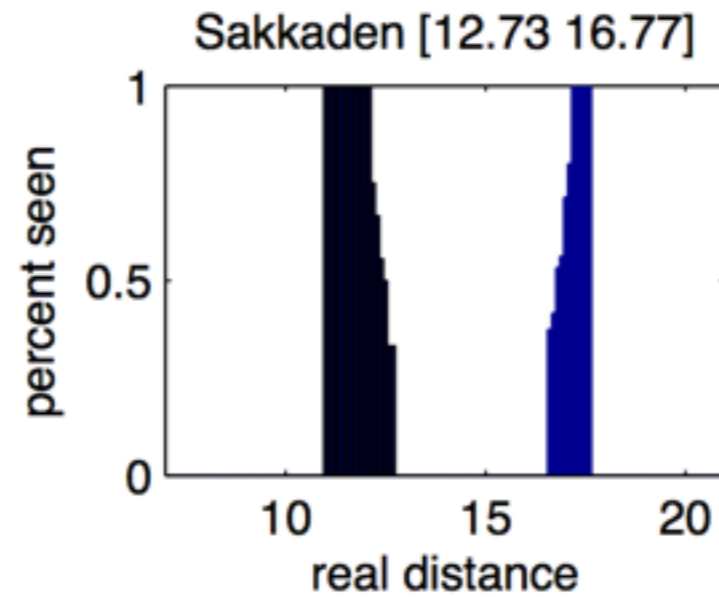
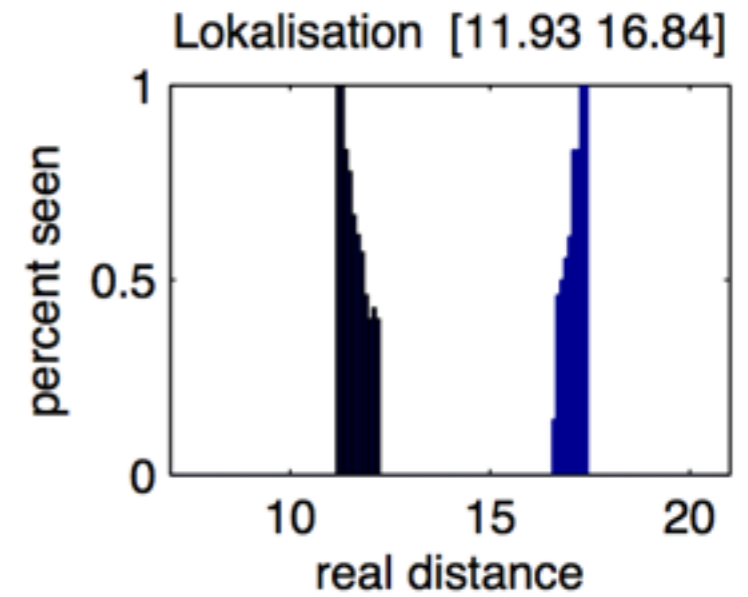
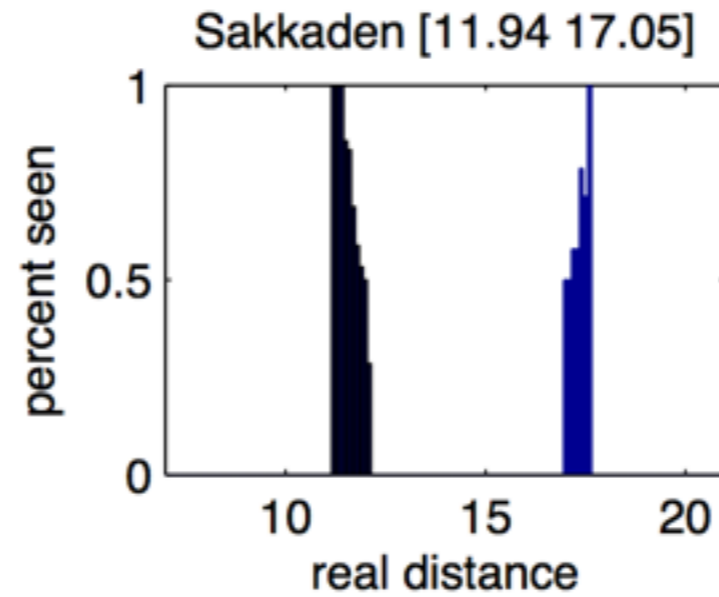
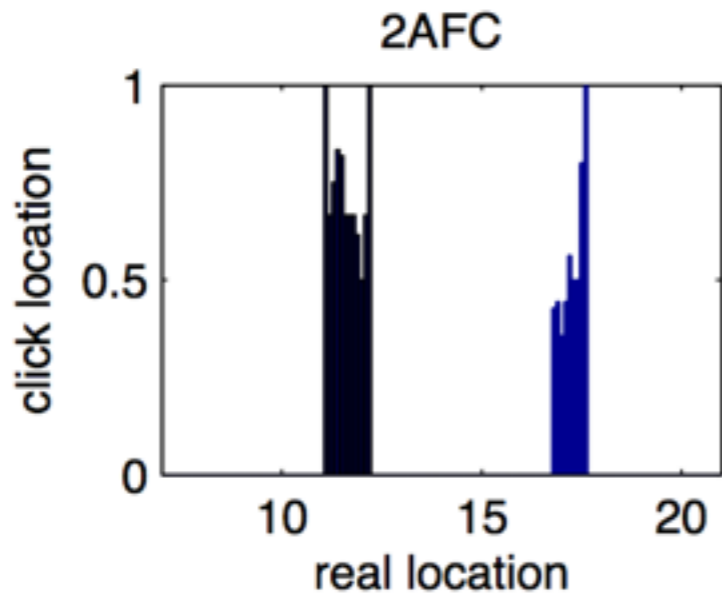
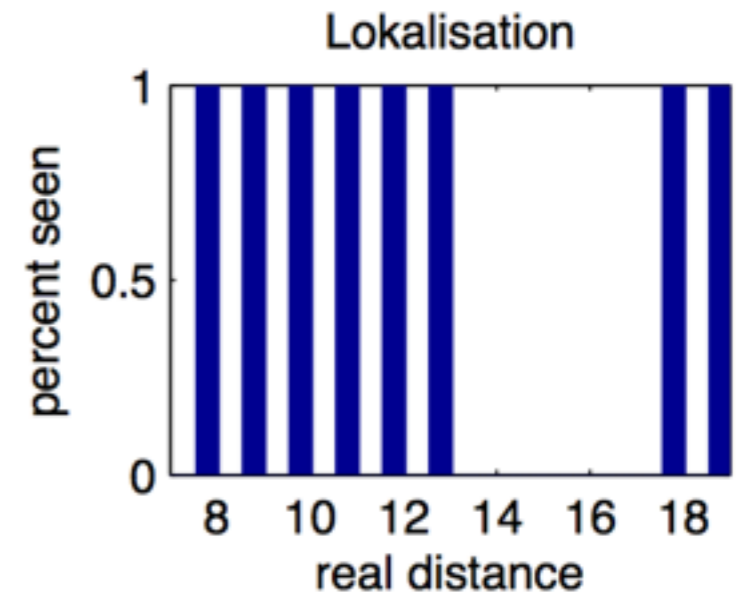
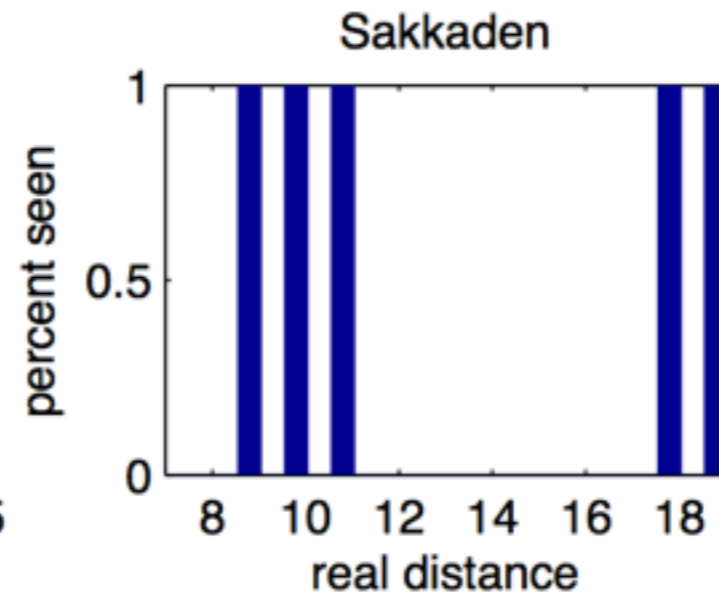
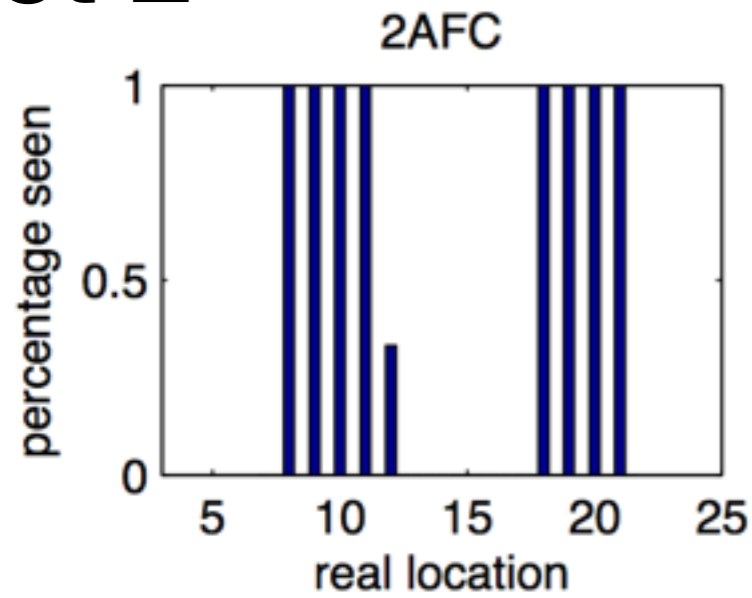
200 ms



Literature

- Armaly, M. F. (1969). The size and location of the normal blind spot. *Archives of Ophthalmology*, 81(2), 192-201.
- Awater, H., Kerlin, J. R., Evans, K. K., & Tong, F. (2005). Cortical representation of space around the blind spot. *Journal of neurophysiology*, 94(5), 3314-3324. Azzi et al. 2015
- Baek, Y., Cha, O., & Chong, S. C. (2012). Characteristics of the filled-in surface at the blind spot. *Vision research*, 58, 33-44.
- Chamlin, M. (1960). Fluctuations in size of the normal blind spot. *Archives of Ophthalmology*, 64(4), 522-527.
- Chen, Z., Maus, G. W., Whitney, D., & Denison, R. N. (2017). Filling-in rivalry: Perceptual alternations in the absence of retinal image conflict. *Journal of vision*, 17(1), 8-8.
- Ehinger, B., König, P., & Ossandón, J. (2015). Prediction of visual content across eye movements and their modulation by inferred information in the blind spot. *Journal of vision*, 15(12), 1304-1304.
- Ehinger, B. V., Häusser, K., Ossandón, J. P., & König, P. (2017). Humans treat unreliable filled-in percepts as more real than veridical ones. *eLife*, 6, e21761.
- Júnior, M. Fiorani., Rosa, M. G., Gattass, R., & Rocha-Miranda, C. E. (1992). Dynamic surrounds of receptive fields in primate striate cortex: a physiological basis for perceptual completion?. *Proceedings of the National Academy of Sciences*, 89(18), 8547-8551.
- Harrington D. Normal Visual Field. In: Mosby (fourth ed). *The Visual Fields – A textbook and atlas of clinical perimetry*. Saint Louis, C.V. Mosby Co. 1976:97-104.
- Dolderer, J., Vonthein, R., Johnson, C. A., Schiefer, U., & Hart, W. (2006). Scotoma mapping by semi-automated kinetic perimetry: the effects of stimulus properties and the speed of subjects' responses. *Acta Ophthalmologica*, 84(3), 338-344.
- Komatsu, H., Kinoshita, M., & Murakami, I. (2000). Neural responses in the retinotopic representation of the blind spot in the macaque V1 to stimuli for perceptual filling-in. *Journal of Neuroscience*, 20(24), 9310-9319.
- Komatsu, H., Kinoshita, M., & Murakami, I. (2002). Neural responses in the primary visual cortex of the monkey during perceptual filling-in at the blind spot. *Neuroscience research*, 44(3), 231-236.
- Komatsu, H. (2006). The neural mechanisms of perceptual filling-in. *Nature Reviews. Neuroscience*, 7(3), 220.
- Matsumoto, M., & Komatsu, H. (2005). Neural responses in the macaque V1 to bar stimuli with various lengths presented on the blind spot. *Journal of neurophysiology*, 93(5), 2374-2387.
- Maus, G. W., & Nijhawan, R. (2008). Motion extrapolation into the blind spot. *Psychological Science*, 19(11), 1087-1091.
- Maus, G. W., & Whitney, D. (2016). Motion-dependent filling-in of spatiotemporal information at the blind spot. *PloS one*, 11(4), e0153896.
- Murakami, I. (1995). Motion aftereffect after monocular adaptation to filled-in motion at the blind spot. *Vision research*, 35(8), 1041-1045.
- Qian, C. S., Brascamp, J. W., & Liu, T. (2017). On the functional order of binocular rivalry and blind spot filling-in. *Vision Research*, 136, 15-20.
- Rhodes M. A systematic review: What is the normative size of the Blind Spot scotoma in adults? *Ophthalmology Research: An international journal*. 2013; 1 (1): 51-66.
- Rhodes, M. J. (2013). Prospective pilot study looking at the size and variation of the blind spot scotoma in adults measured on the Octopus 900 Field Analyser. *METHODOLOGY*, 48, 49.
- Safran AB, Mermillod B, Mermoud C, DeWeisse C, Desangles D. Characteristic features of blind spot size and location, when evaluated with automated perimetry—values obtained in normal subjects. *Neuro-Ophthalmology*. 1993; 13: 309–315.
- Spillmann L, Otte T, Hamburger K, Magnussen S. Perceptual filling-in from the edge of the blind spot. *Vision Res*. 2006; 46: 4252–4257. doi: 10.1016/j.visres.2006.08.033 PMID: 17034833
- Tong, F., & Engel, S. A. (2001). Interocular rivalry revealed in the human cortical blind-spot representation. *Nature*, 411(6834), 195.
- Tootell, R. B., Hadjikhani, N. K., Vanduffel, W., Liu, A. K., Mendola, J. D., Sereno, M. I., & Dale, A. M. (1998). Functional analysis of primary visual cortex (V1) in humans. *Proceedings of the National Academy of Sciences*, 95(3), 811-817.
- Traquair H. *The Normal Field of Vision*. In: Kimpton (fifth ed). *An introduction to Clinical Perimetry*. London, Henry Kimpton. 1948:14-16.
- Tripathy, S. P., Levi, D. M., & Ogmen, H. (1996). Two-dot alignment across the physiological blind spot. *Vision research*, 36(11), 1585-1596.
- Weil, R. S., & Rees, G. (2011). A new taxonomy for perceptual filling-in. *Brain research reviews*, 67(1), 40-55.

Subject 2



17 ms

200 ms