Palacký University Olomouc
Faculty of Science
Department of Optics

Psychophysical measurements of visual functions: crowding and contour interaction

Lenka Musilová

Olomouc 2019

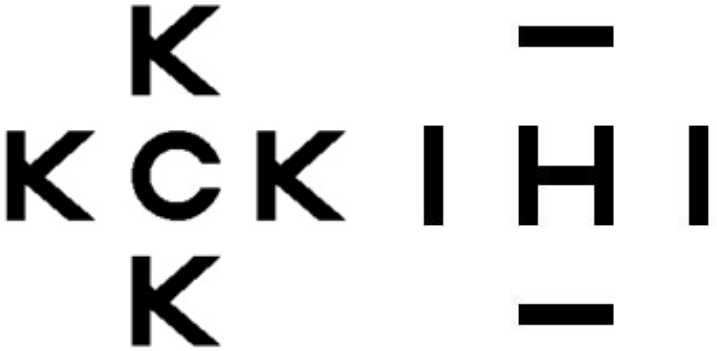
Outline

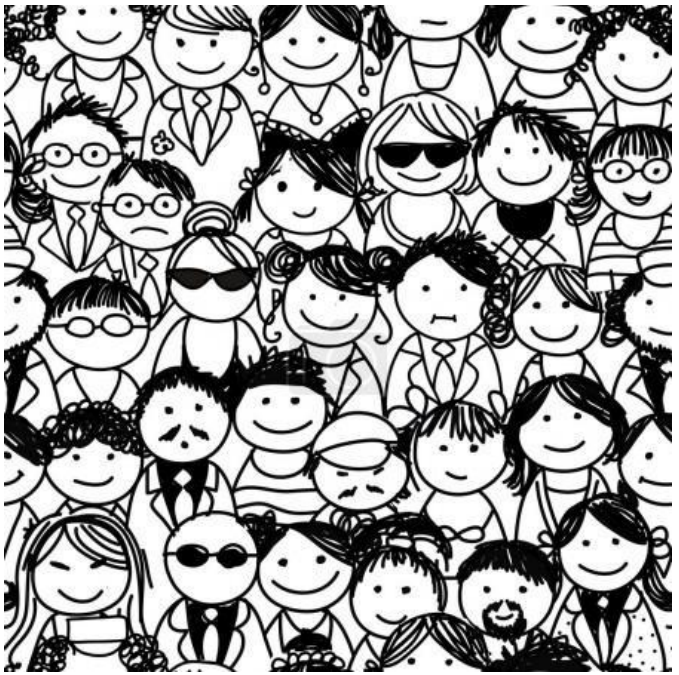
- Introduction
- Experiments
- Conclusion – summary of the main results
- Publishing activity

Introduction

Physiological optics:

- Crowding effect
- Contour interaction





Introduction

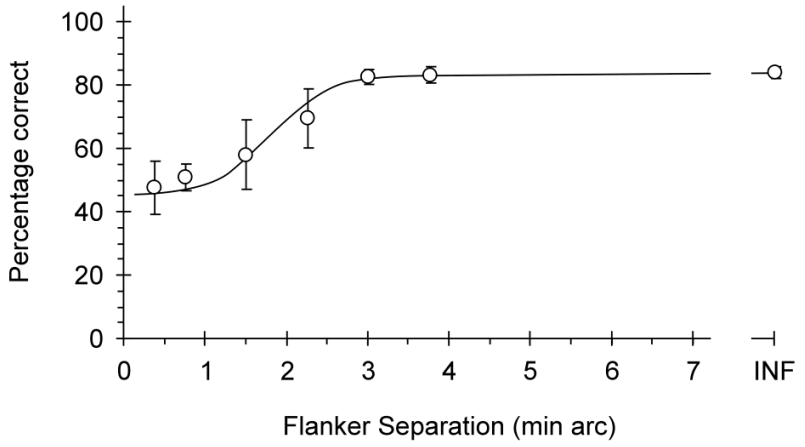
Crowding and contour interaction:

Extent (critical spacing)

- critical separation (between central target and flankers) at which identification of acuity targets is reduced

Magnitude

- maximum reduction of target identification

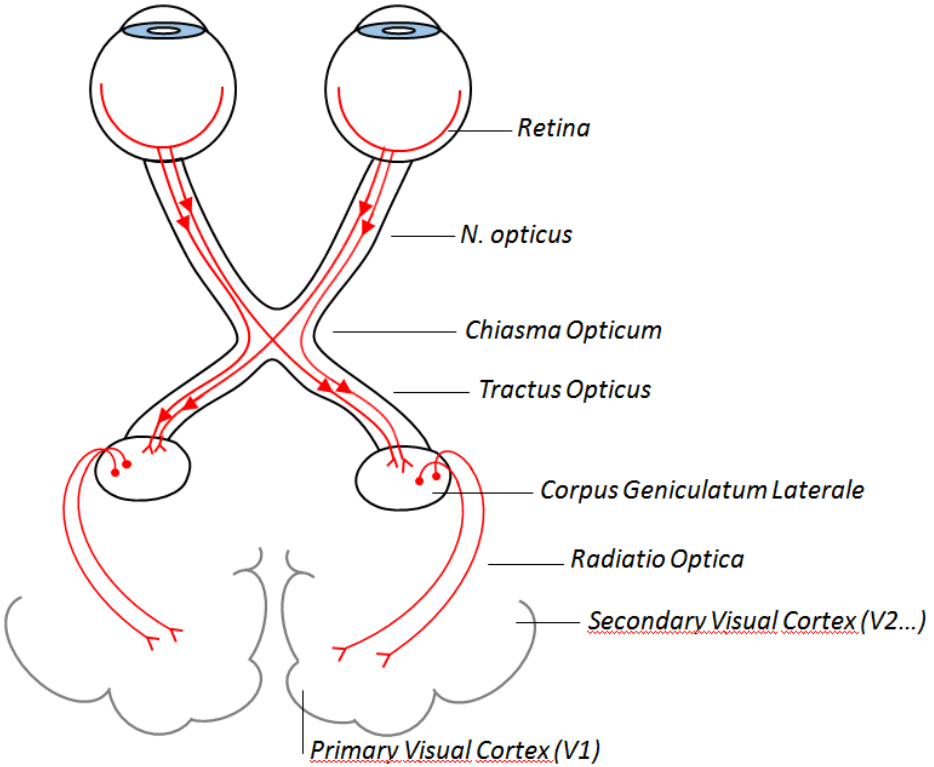


Introduction

- explanation of origin these physiological effects
- several hypothesis
- most likely cause: **neural origin**

  (signal prosessing at the neural level of receptive fields in visual pathway)

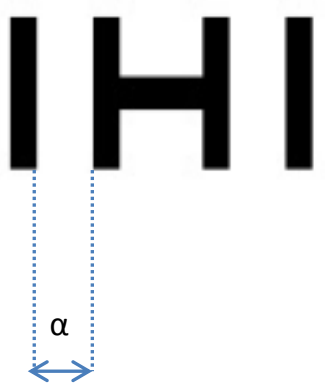
- eye movements
- inattention



Introduction

Used methods of measurement:

- **Analysis of changes in visual performance**
- **Constant target size** (under given conditions)



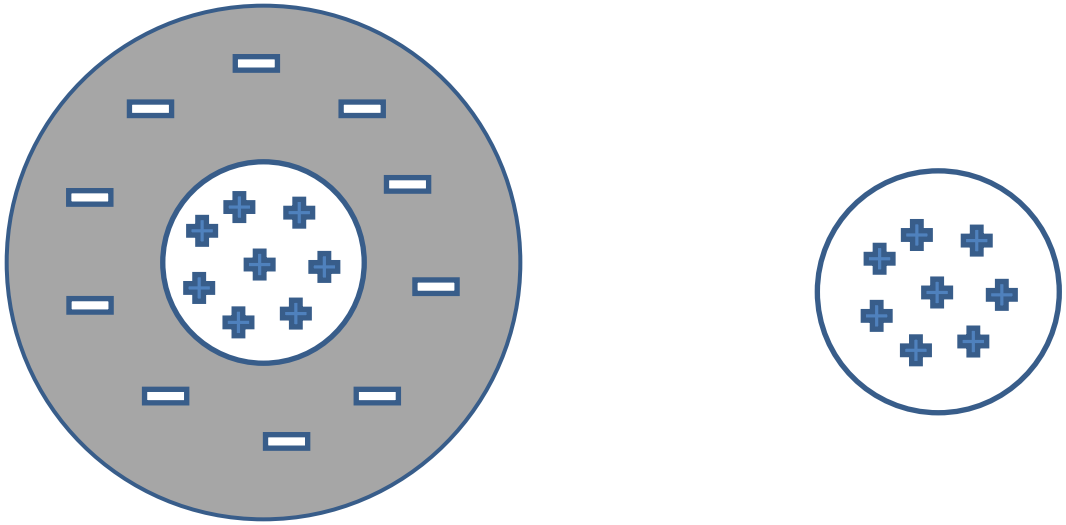
- **Effect of flankers in different separations (α)**
- **Influence of different conditions**
  - luminance, excentricity (Study I – II)
  - type, number, position of flankers (Study III – IV)

Experiments

Study I – II: main idea:

Neural origin – antagonistic structure of receptive field

on-centrum



photopic ----------> scotopic

Experiments

Contour interaction for foveal acuity targets at different luminances (Study I):

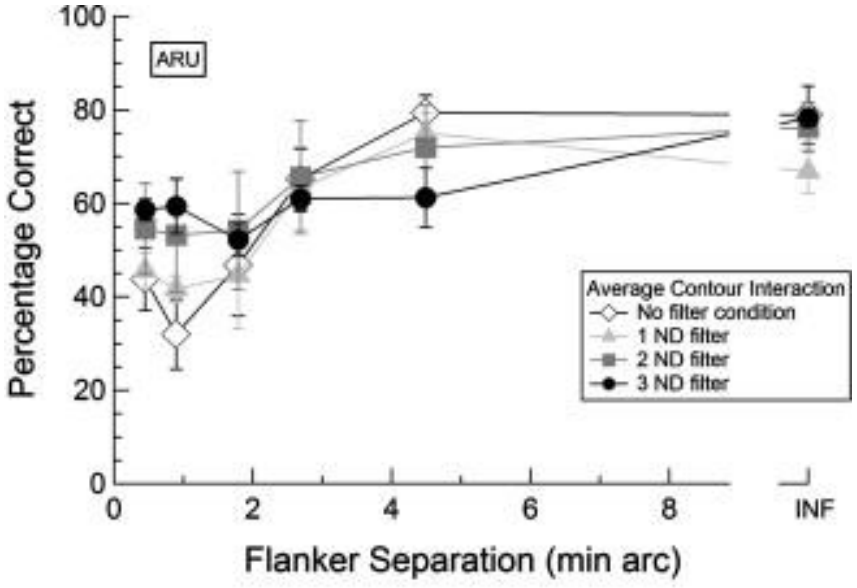
Aim:

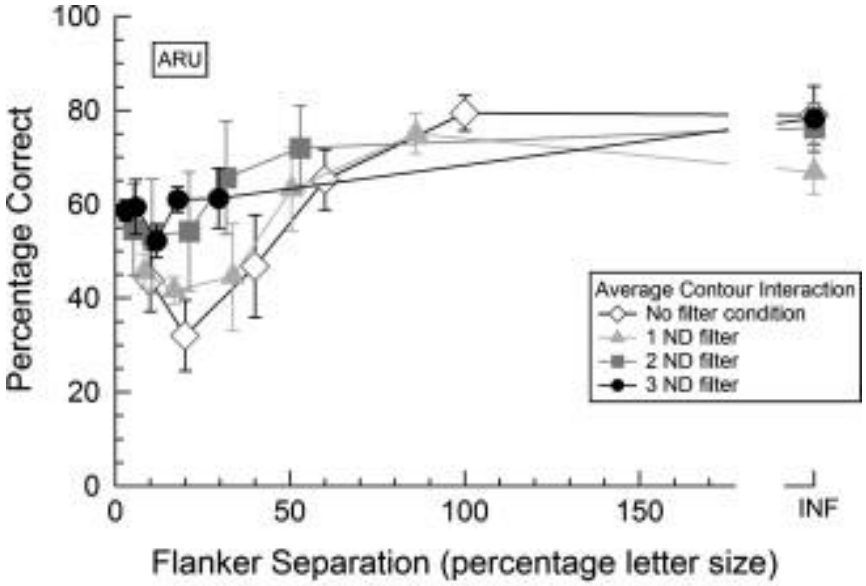
What are the changes of foveal contour interaction in luminance reduction?

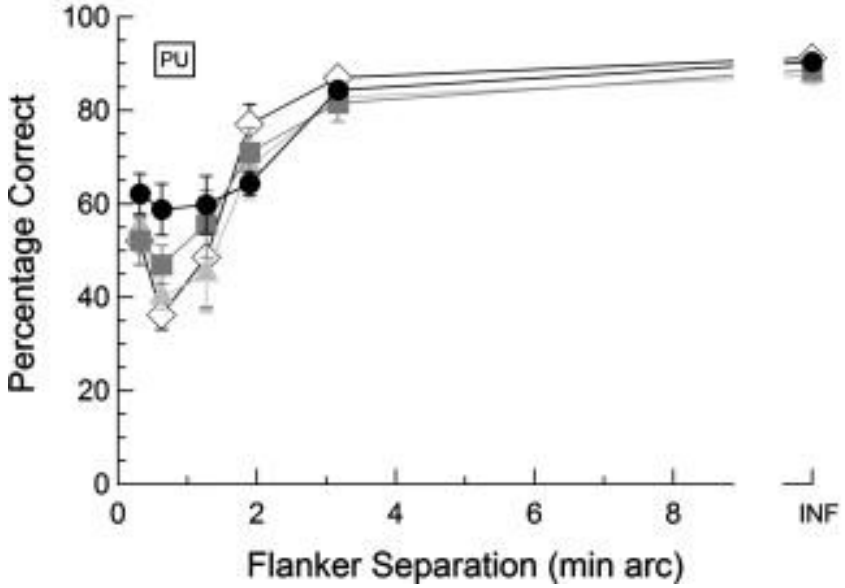
(fotopic/mesopic level)

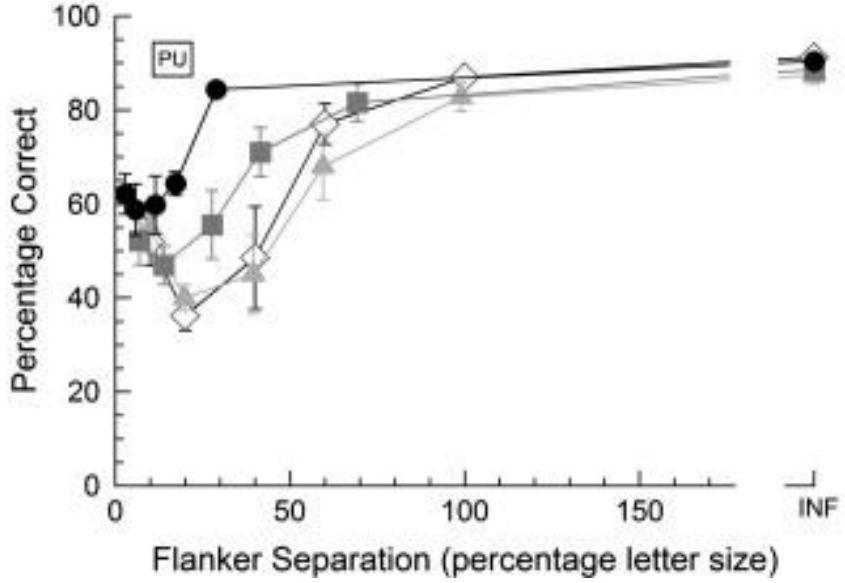
Methods:

- 10 normal observers at two laboratories (UP, Czech Republic; Anglia Ruskin University, UK)
- stimuli: randomly selected **Sloan letter** surrounded by **4 equally spaced bars** for 5 separations, viewed **foveally**
- four different background luminances


ARU
Percentage Correct
Flanker Separation (min arc)
Average Contour Interaction
No filter condition
1 ND filter
2 ND filter
3 ND filter
0
2
4
6
8
INF
0
20
40
60
80
100


ARU
Percentage Correct
Flanker Separation (percentage letter size)
Average Contour Interaction
No filter condition
1 ND filter
2 ND filter
3 ND filter
0
50
100
150
INF
0
20
40
60
80
100


PU
Percentage Correct
Flanker Separation (min arc)
0
2
4
6
8
INF
0
20
40
60
80
100


PU
Percentage Correct
Flanker Separation (percentage letter size)
0
50
100
150
INF
0
20
40
60
80
100

Results

- **systematic reduction in the magnitude** of contour interaction as the background luminance is reduced
- significant main effect of separation, interaction between luminance and flank separation for both groups of observers
- **extent of contour interaction**, in min arc, remains essentially **unchanged**
- extent of contour interaction for foveal acuity targets is similar for different background luminances

Conclusion

- explanation for contour interaction can be based on **antagonistic neural interaction of receptive field**

Experiments

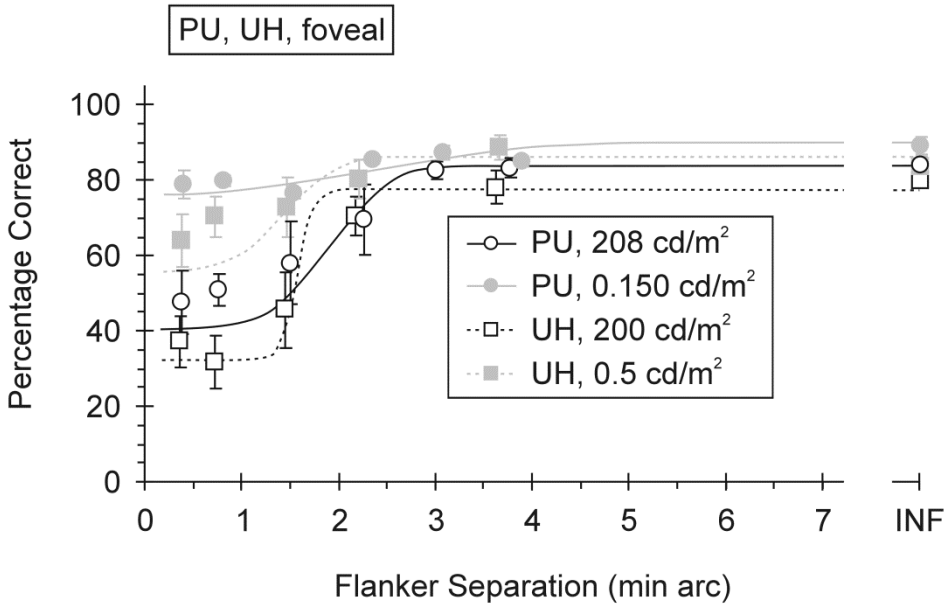
Contour interaction under photopic and scotopic conditions (Study II):

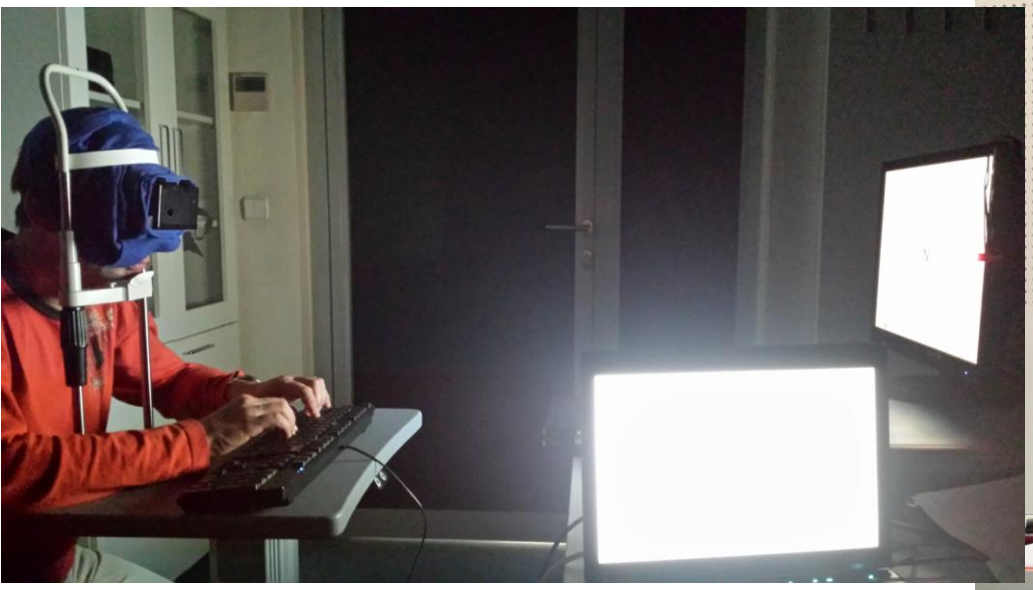
Aim:

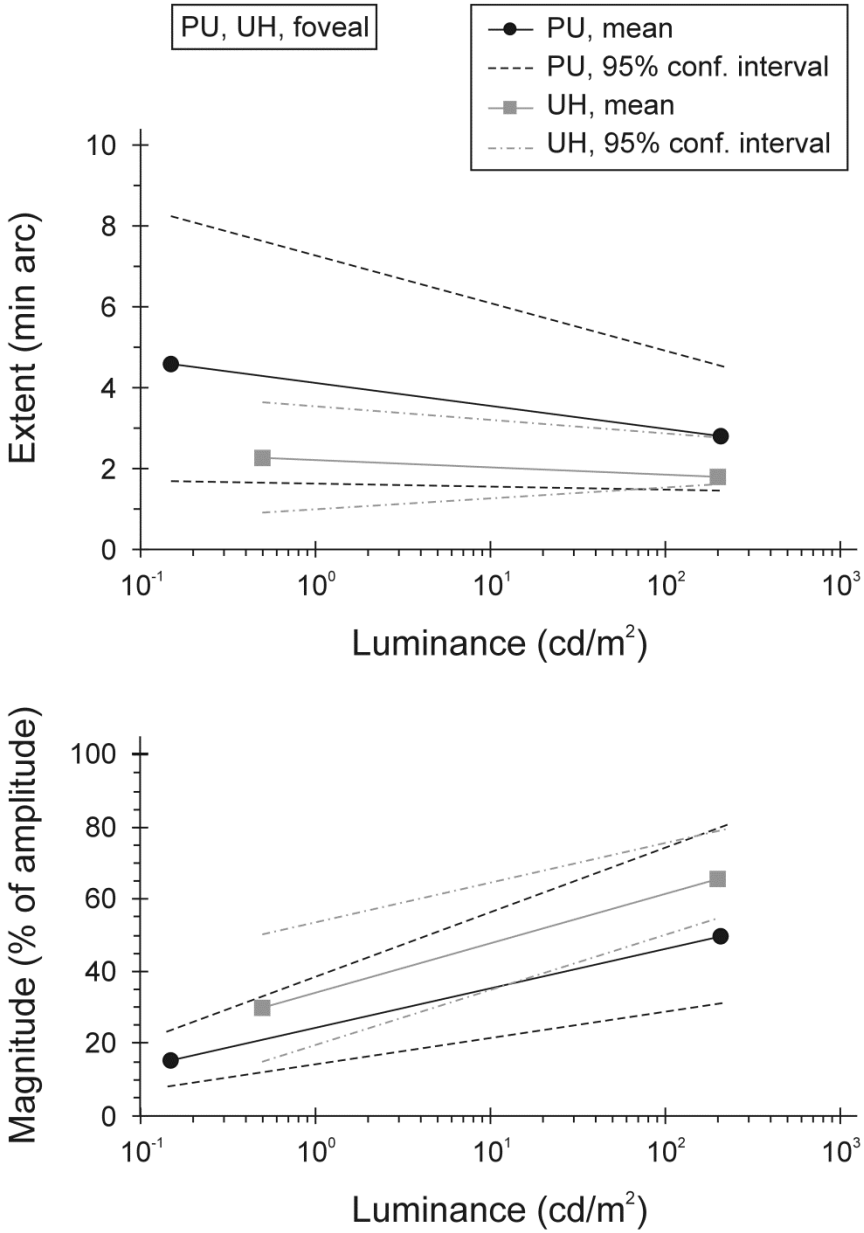
Comparison of contour interaction measured foveally and at different retinal eccentricities for targets of photopic, mesopic and scotopic luminances

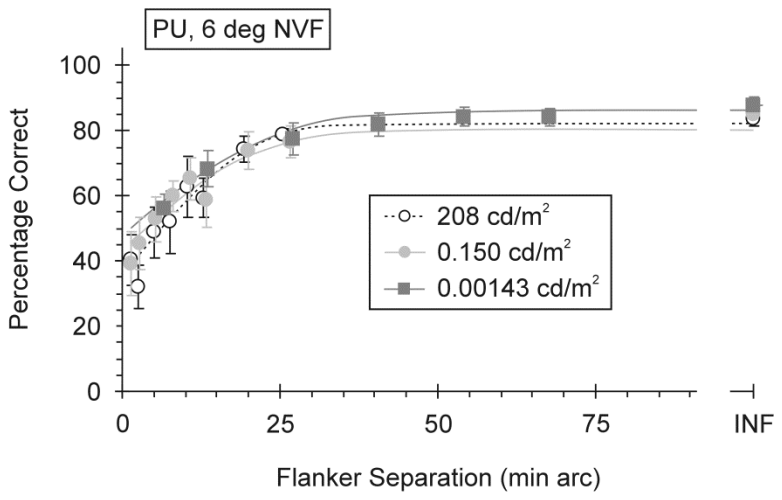
Methods:

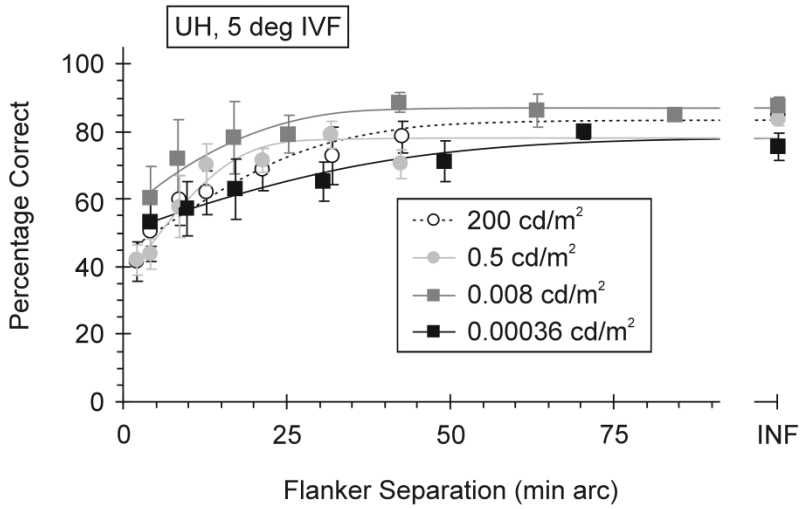
- 9 normal observers at two laboratories (UP, Czech Republic; University of Houston, USA)
- randomly selected Sloan letter surrounded by 4 equally spaced bars for several separations
- stimuli: viewed **foveally/peripherally** (UP: 6 and 12 deg; UH: 5 and 10 deg)
- four different background luminances of the display monitors: corresponding to **photopic, mesopic, scotopic** and **dim scotopic** levels

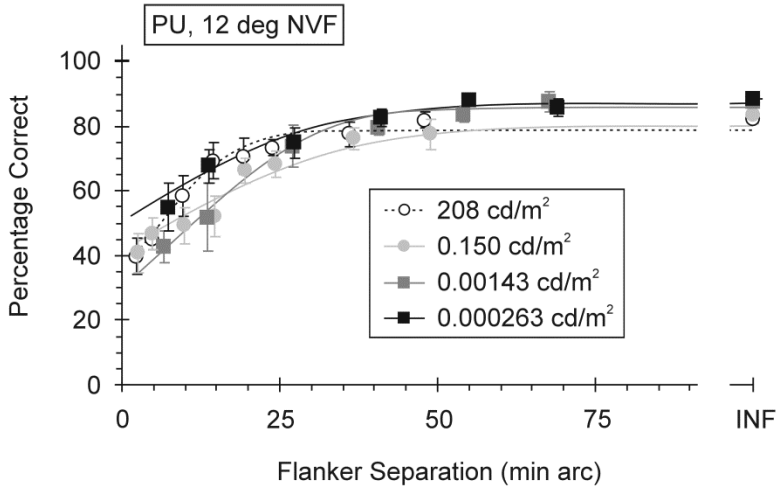

PU, UH, foveal
Percentage Correct
100
80
60
40
20
0
0
1
2
3
4
5
6
7
INF
Flanker Separation (min arc)
PU, 208 cd/m²
PU, 0.150 cd/m²
UH, 200 cd/m²
UH, 0.5 cd/m²

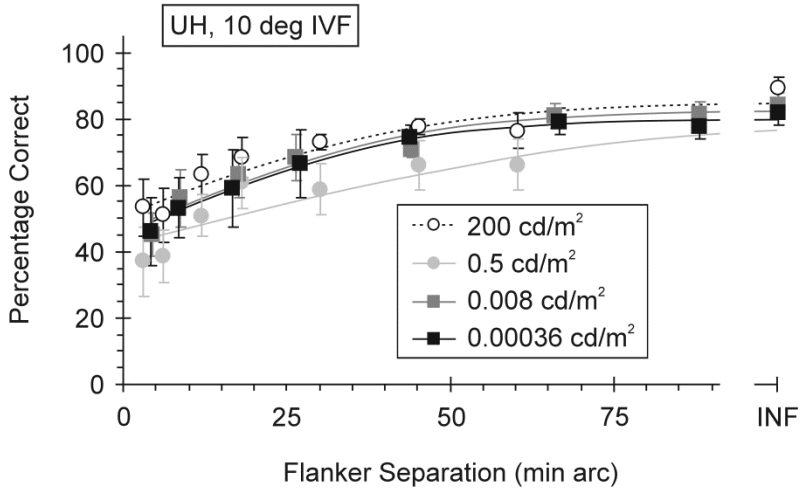


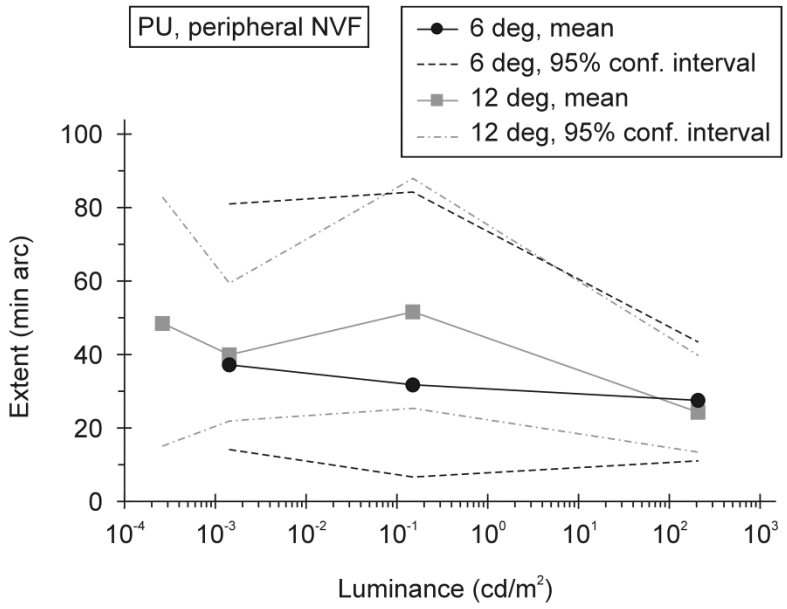

PU, UH, foveal
PU, mean
PU, 95% conf. interval
UH, mean
UH, 95% conf. interval
Extent (min arc)
Luminance (cd/m²)
Magnitude (% of amplitude)
Luminance (cd/m²)

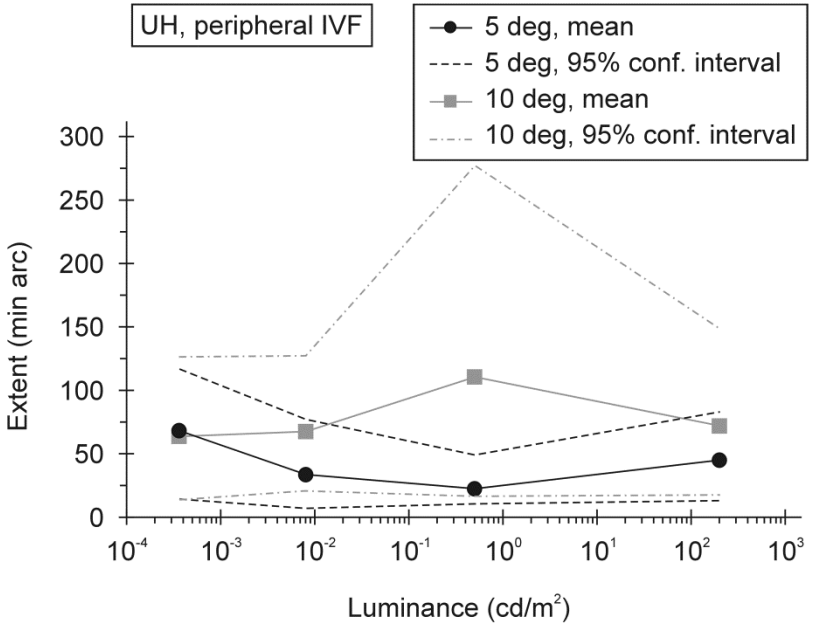

PU, 6 deg NVF
Percentage Correct
100
80
60
40
20
0
0
25
50
75
INF
Flanker Separation (min arc)
208 cd/m²
0.150 cd/m²
0.00143 cd/m²

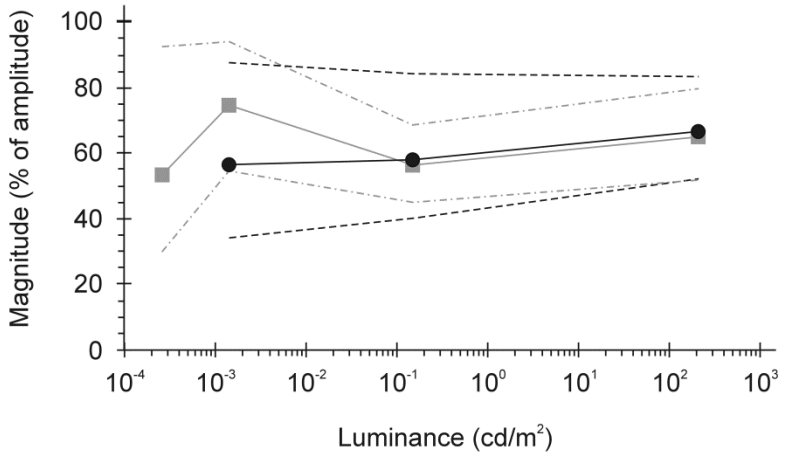

UH, 5 deg IVF
Percentage Correct
100
80
60
40
20
0
0
25
50
75
INF
Flanker Separation (min arc)
200 cd/m²
0.5 cd/m²
0.008 cd/m²
0.00036 cd/m²

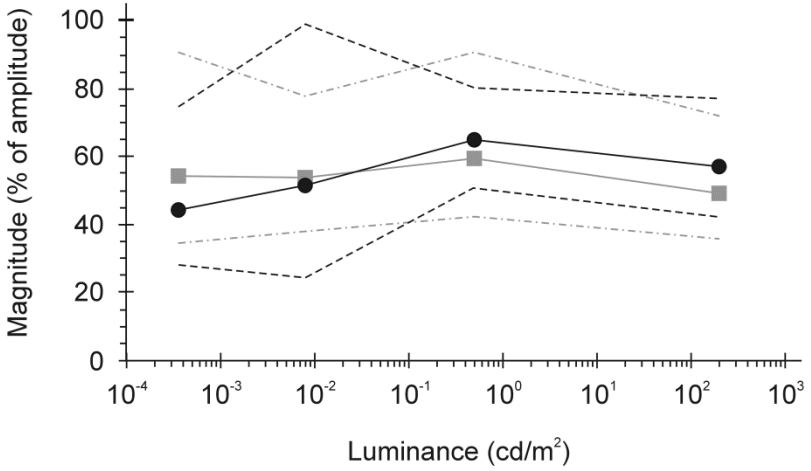

PU, 12 deg NVF
Percentage Correct
100
80
60
40
20
0
0
25
50
75
INF
Flanker Separation (min arc)
208 cd/m²
0.150 cd/m²
0.00143 cd/m²
0.000263 cd/m²


UH, 10 deg IVF
Percentage Correct
100
80
60
40
20
0
0
25
50
75
INF
Flanker Separation (min arc)
200 cd/m²
0.5 cd/m²
0.008 cd/m²
0.00036 cd/m²


PU, peripheral NVF
6 deg, mean
6 deg, 95% conf. interval
12 deg, mean
12 deg, 95% conf. interval
Extent (min arc)
Luminance (cd/m²)


UH, peripheral IVF
5 deg, mean
5 deg, 95% conf. interval
10 deg, mean
10 deg, 95% conf. interval
Extent (min arc)
Luminance (cd/m²)


Magnitude (% of amplitude)
Luminance (cd/m²)


Magnitude (% of amplitude)
Luminance (cd/m²)

Results

- **Fovea:** reduction of magnitude and constant extent with luminance decrease

- **Periphery**: no influence of luminance and eccentricity on extent and magnitude

  Extent in pheriphery is approximately twenty times larger than in fovea.

Conclusion

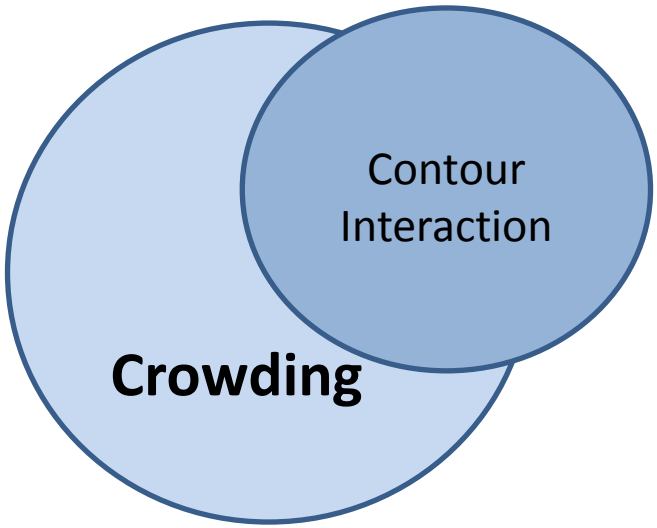
Both **foveal** and **peripheral contour interaction** data can be accounted for **neural origin**,

foveal contour intreaction was proved on **antagonism of receptive field**.

Experiments

Study III – IV, main idea:

Is foveal crowding more complex effect than foveal contour interaction?



Experiments

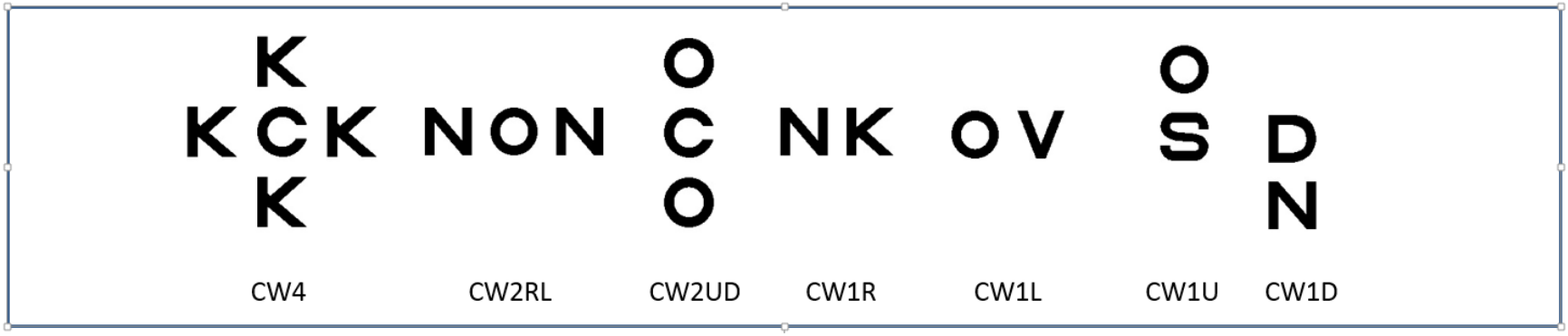
Number of flankers influences crowding and contour interaction differently (Study III):

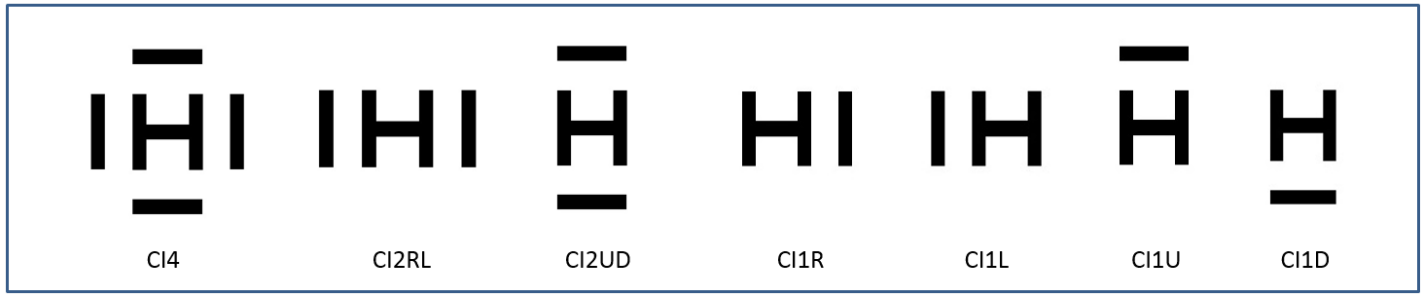
Aim:

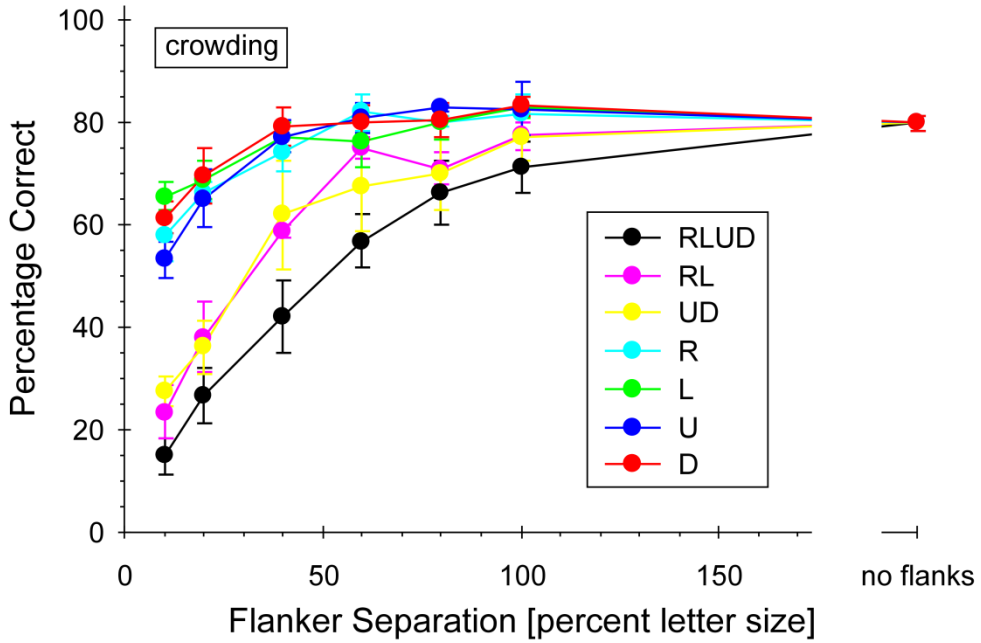
Comparison of crowding and contour interaction in fovea (with the different number flankers)

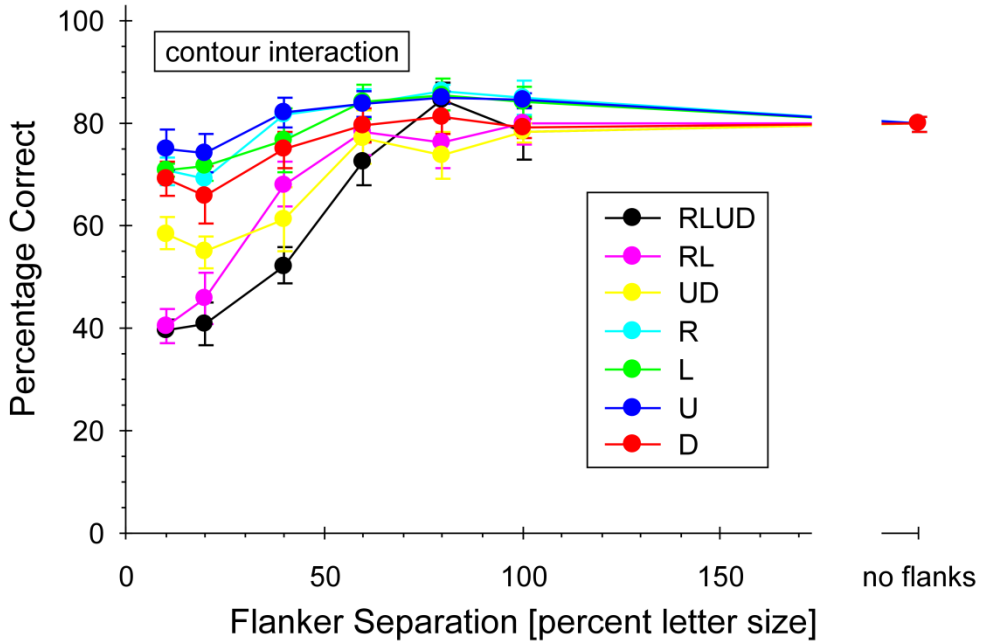
Methods:

- 5 normal observers at two laboratories (UP, Czech Republic; Anglia Ruskin University, UK)
- randomly selected **Sloan letter** surrounded by **bars or flankers (letters)** for 6 separations; different numbers of bars and flankers were presented
- stimuli: viewed **foveally; photopic** level of luminance


CW4
CW2RL
CW2UD
CW1R
CW1L
CW1U
CW1D


CI4
CI2RL
CI2UD
CI1R
CI1L
CI1U
CI1D


crowding
Percentage Correct
100
80
60
40
20
0
0
50
100
150
no flanks
Flanker Separation [percent letter size]
RLUD
RL
UD
R
L
U
D


contour interaction
Percentage Correct
100
80
60
40
20
0
0
50
100
150
no flanks
Flanker Separation [percent letter size]
RLUD
RL
UD
R
L
U
D

Results

- significant main effect of separation for crowding and contour interaction
- significant main effect of number of flankers
- significant main effect of interactions between number of flankers and separations and between type of flankers and separations

Conclusion

- we found differences between crowding and contour interaction
- crowding is stronger for small separations and four flankers

Experiments

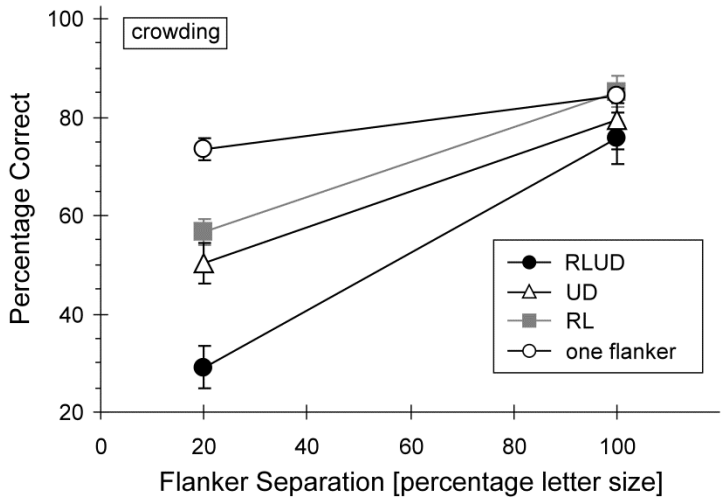
Error analysis for crowding and contour interaction (Study IV):

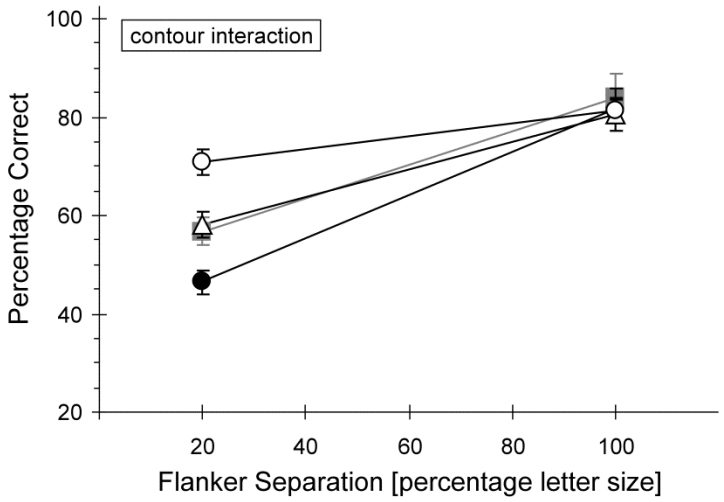
Aim:

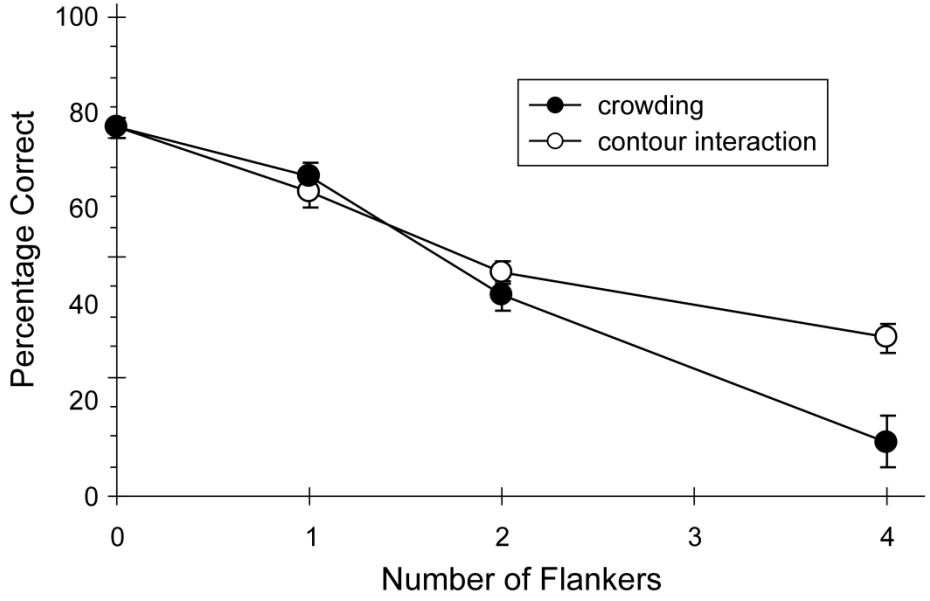
Comparison of error matrices for crowding and contour interaction

Methods:

- 4 normal observers at two laboratories (UP, Czech Republic; Anglia Ruskin University, UK)
- randomly selected **Sloan letter** surrounded by **bars or flankers (letters)** for 2 separations; different numbers of bars and flankers were presented
- stimuli: viewed **foveally; photopic** level of luminance
- 1000 presentation per condition and observer


crowding
Percentage Correct
Flanker Separation [percentage letter size]
RLUD
UD
RL
one flanker


contour interaction
Percentage Correct
Flanker Separation [percentage letter size]


crowding
contour interaction
Percentage Correct
Number of Flankers

Response

Contour interaction

Presented target

	C	D	H	K	N	O	R	S	V	Z
C	0,50	0,08	0,02	0,09	0,02	0,06	0,06	0,07	0,02	0,10
D	0,28	0,18	0,06	0,09	0,05	0,15	0,06	0,06	0,02	0,05
H	0,01	0,02	0,69	0,02	0,15	0,04	0,03	0,01	0,02	0,01
K	0,09	0,01	0,02	0,52	0,01	0,02	0,13	0,04	0,01	0,15
N	0,02	0,03	0,51	0,03	0,26	0,05	0,04	0,03	0,01	0,01
O	0,26	0,09	0,06	0,06	0,04	0,18	0,08	0,13	0,02	0,07
R	0,04	0,02	0,21	0,11	0,05	0,03	0,32	0,17	0,01	0,06
S	0,02	0,02	0,02	0,03	0,01	0,01	0,14	0,58	0,02	0,16
V	0,02	0,02	0,03	0,03	0,01	0,02	0,05	0,01	0,59	0,23
Z	0,00	0,01	0,01	0,03	0,01	0,00	0,07	0,04	0,03	0,79

Response

Crowding

Presented target

	C	D	H	K	N	O	R	S	V	Z
C	0,21	0,11	0,06	0,11	0,07	0,11	0,04	0,10	0,08	0,11
D	0,11	0,27	0,10	0,15	0,07	0,11	0,06	0,06	0,04	0,04
H	0,02	0,12	0,48	0,10	0,17	0,02	0,04	0,02	0,02	0,02
K	0,03	0,11	0,11	0,24	0,17	0,04	0,10	0,04	0,09	0,08
N	0,03	0,13	0,41	0,14	0,12	0,02	0,08	0,02	0,01	0,02
O	0,08	0,21	0,12	0,13	0,08	0,08	0,07	0,11	0,05	0,08
R	0,02	0,11	0,20	0,11	0,12	0,05	0,24	0,11	0,01	0,03
S	0,04	0,10	0,10	0,09	0,10	0,07	0,14	0,23	0,05	0,10
V	0,03	0,02	0,04	0,03	0,11	0,03	0,01	0,03	0,57	0,13
Z	0,05	0,03	0,03	0,04	0,04	0,05	0,03	0,06	0,20	0,46

Response

Reference matrix

Presented target

	C	D	H	K	N	O	R	S	V	Z
C	0,84	0,04	0,00	0,01	0,00	0,05	0,00	0,03	0,01	0,01
D	0,03	0,78	0,01	0,00	0,00	0,12	0,03	0,01	0,00	0,01
H	0,00	0,01	0,73	0,01	0,22	0,00	0,02	0,00	0,00	
K	0,02	0,00	0,00	0,86	0,01	0,00	0,01	0,01	0,06	0,02
N	0,00	0,01	0,13	0,02	0,81	0,00	0,03	0,00	0,01	
O	0,09	0,22	0,00	0,00	0,01	0,63	0,02	0,04		0,00
R	0,00	0,01	0,01	0,03	0,11	0,01	0,76	0,06	0,00	0,00
S	0,05	0,04	0,00	0,02	0,01	0,03	0,05	0,79	0,01	0,02
V	0,01			0,01	0,00	0,00	0,00		0,98	0,00
Z	0,01	0,00	0,00	0,01	0,00	0,00	0,00	0,01	0,01	0,95

Color scale

no change
(0,00; 0,05)
<0,05; 0,10)
<0,10; 0,20)
<0,20; 0,30)
<0,30; 0,40)
<0,40; 1,00)

Response

Presented target

	C	D	H	K	N	O	R	S	V	Z
C									CW	
D	CI			CW						
H		CW		CW	CI					
K	CI	CW	CW		CW		CI		CW	CI
N		CW	CI	CW						
O	CI	CW		CW						
R		CW			CW			CI		
S		CW	CW		CW	CW	CI			CI
V					CW		CI			CI
Z							CI		CW	

Conclusion

Crowding is a complex phenomenon, which includes other similar effects as contour interaction, but also other effects (especially substitution).

Conclusion – summary fo the main results (Study I – II)

Foveal contour interaction:

- similar extent under fotopic and mesopic luminaces
- systematic reduction of magnitude as the background luminance is reduced, consistent with the changes in receptive fields structure.

Periferal contour interaction:

- does not show significant changes of extent and magnitude magnitudy depending on eccentricity and luminance.

Contour interaction has smaller extent in the fovea than in the periphery.

⇒ **neural origin**

⇒ **in fovea based on antagonistic structure of receptive fields of visual pathway**

Conclusion – summary fo the main results (Study III – IV)

⇒ **crowding is a complex phenomenon compared to contour interaction**

⇒ **includes other similar effects, connected with contour interaction (antagonism of receptive fields, substitution) or directly contour interaction**

Publishing activity

[A1] Musilová, L., Pluháček, F., Marten-Ellis, S. M., Bedell, H. E., Siderov, J. (2018). ***Contour interaction under photopic and scotopic conditions.*** Journal of Vision, 18(6), doi: 10.1167/18.6.5

[A2] Bedell, H. E., Siderov J., Waugh S. J., Zemanová, R., Pluháček, F., Musilová, L. (2013). ***Contour interaction for foveal acuity targets at different luminances.*** Vision Research, 89, 90-95

[A3] Musilová, L., Pluháček, F., Bedell, H. E., Marten-Ellis, S. M., Siderov, J. (2017). ***Peripheral contour interaction is similar under photopic and scotopic luminances.*** Investigative Ophthalmology & Visual Science, 58(8), 4217

[A4] Musilová, L., Pluháček, F., Bedell, H. E., Siderov, J. (2018). ***Number of flankers influences crowding and contour interaction differently*.** Investigative Ophthalmology & Visual Science, 59(9), 1079

Thank you for your attention

Anglia Ruskin University

Cambridge & Chelmsford