Surround suppression effect in human early visual cortex contributes to illusory contour processing: MEG evidence

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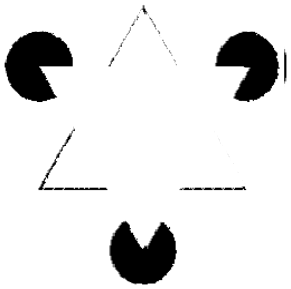
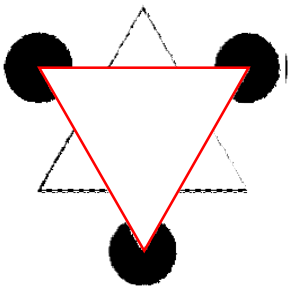
Исследование осуществлено в рамках программы фундаментальных исследований НИУ ВШЭ

Kanizsa triangle (Kanizsa, 1955)



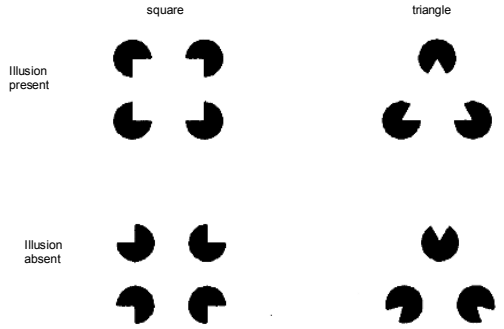
Kanizsa triangle (Kanizsa, 1955)



Illusory contours are perceived automatically at preattentional level

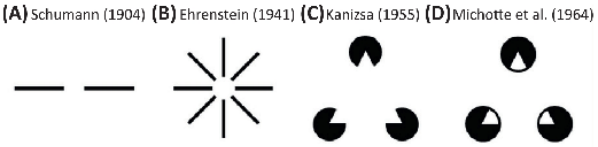
✷ Attention is not needed for perception of illusory contours – thus illusory contour completion is automatic (Vuilleumier, Landis, 1998; Davis and Driver, 1994; Senkowski et al., 2005)

Typical stimuli used to study illusory contours: Kanizsa figures



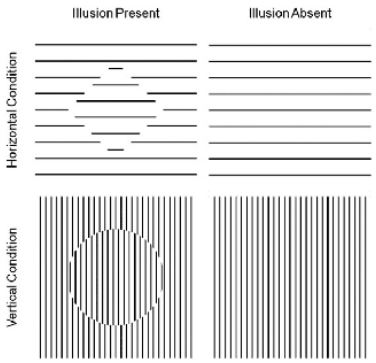
Herrmann Mecklinger 2000

Examples of illusory contours



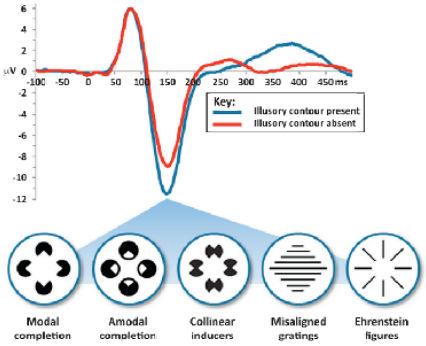
Murray Herrmann 2013

Typical stimuli used to study illusory contours: abutting gratings



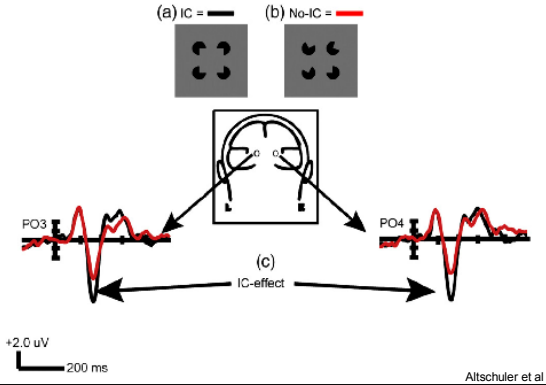
Knebel Murray 2012

N1 response is increased to illusory contours (the effect was initially reported by Sugawara and Morotomi (1991)



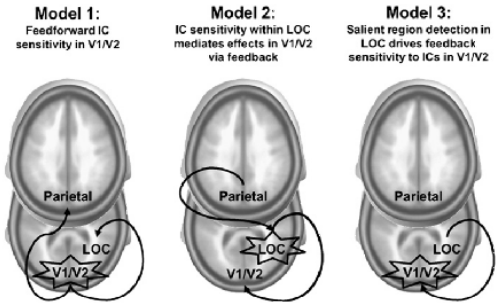
Murray Herrmann 2013

The illusory contour effect is generated in the lateral occipital area (lateral occipital complex, LOC)



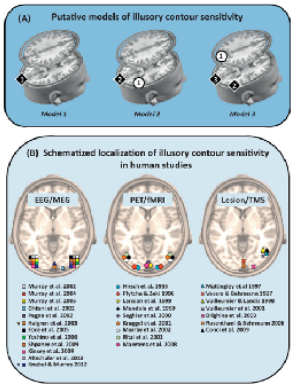
Altschuler et al 2012

Three competing models for illusory contours sensitivity



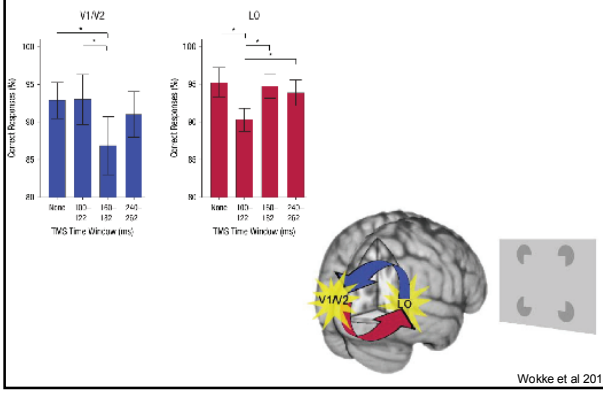
Knebel Murray 2012

Putative models of illusory contour sensitivity



Murray Herrmann 2013

Feed-forward/feedback loop between V1/V2 and LO that occurs during perceptual completion

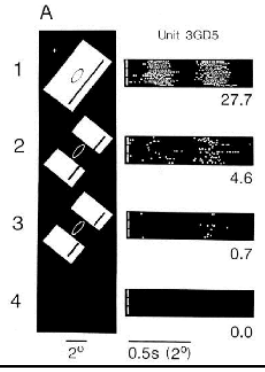


Wokke et al 2013

The role of the primary visual cortex in OC perception is not currently known

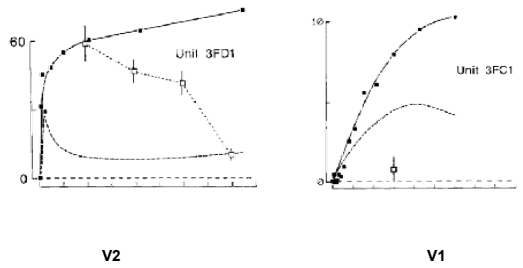
- We focused on early events occurring at the lower-tier levels of visual processing
- We were searching for the inverted IC effect (smaller response to illusory contour compared with controls)

Many V2 neurons and some V1 neurons respond to illusory contours, when all real parts of the contour are outside the cells receptive field



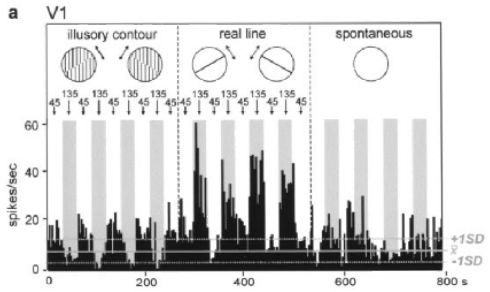
Peterhans Heydt 1989

While V2 cells responded to ICs stronger than predicted from summation of responses to bars



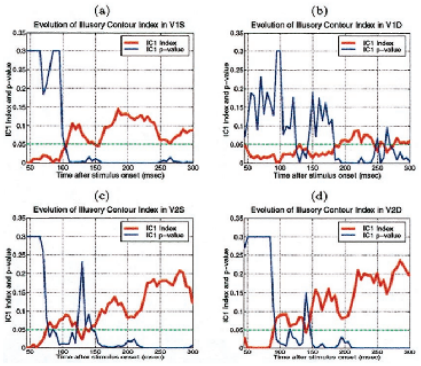
Peterhans Heydt 1989

V1 neurons may be inhibited by illusory contours



Ramsden et all 2001

Activity in V1/V2



Lee Nguyen 2001

Collinearity is required for Kanizsa-like illusory contour completions

- Collinearly of aligned boundaries was shown to play the primary role in illusory contour perception and in the IC effect produced by Kanizsa-like figures (Proverbio & Zani, 2002).
- Collineral checkerboard increases Kanizsa illusion if it is collinear with the illusory contours (Ramachadran et al., 1994).

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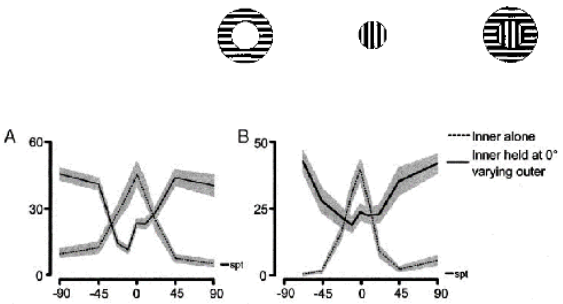
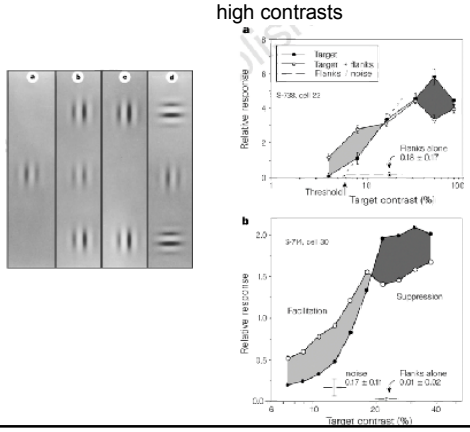
Orthogonal stimuli outside the cell's receptive field induce surround facilitation, while collinear stimuli induce suppression



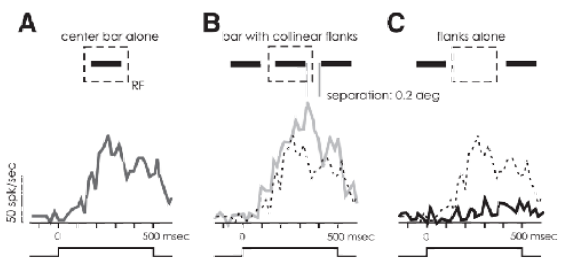
Jones Wang Sillito 2002

Collinearity leads to surround suppression in V1 at sufficiently high contrasts



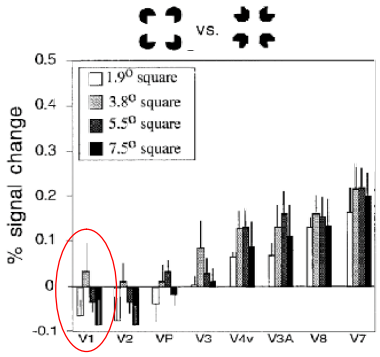
Polat et al 1998

Surround suppression could be observed in response to illusory contours formed collinear bars (optical imaging of V1 in monkeys)



Kinoshita et al 2009

fMRI: decreased response to Kanizsa figures in V1 and V2

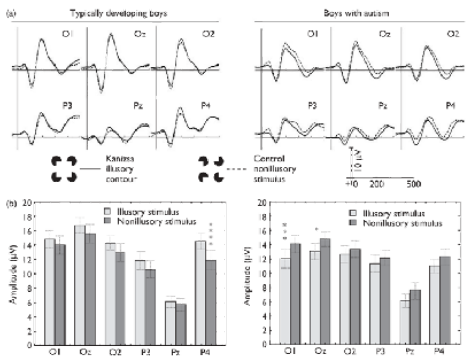


Mendola et al 1999

fMRT studies: Gestalt perception suppresses activity in V1

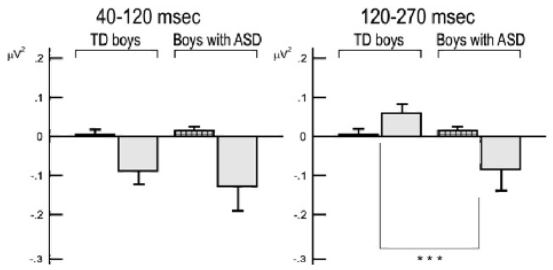
- Gestalt perception was found to robustly suppress fMRI signal within early retinotopic areas (Murray et al., 2002b; Fang et al., 2008; de-Wit et al., 2012).

ERP study: IC effect was inverted in autistic children



Stroganova et al 2007

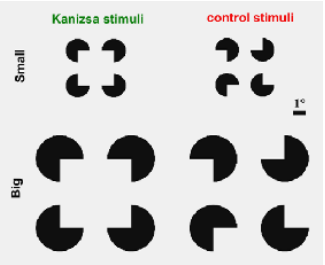
Phase-locked gamma activity: inverted effect during 40-120 ms in both normal and autistic children, difference within 120-270 ms



Stroganova et al 2012

Methods: visual stimuli

- Visual stimuli (Kanizsa figure and control) presented in random order.
- Two stimulus sizes:
  small 4.5° x 4.5° (fitting within the parafoveal vision area)
  big 9.0° x 9.0° (extending beyond the boundaries of the parafoveal vision)



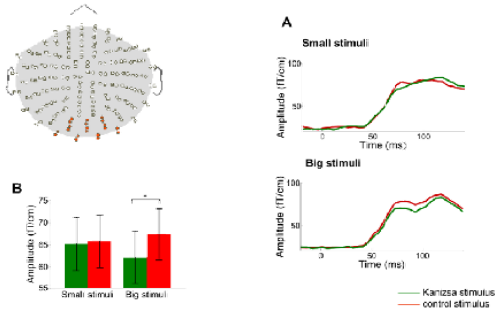
Chernyshev et al – submitted to EJN

Methods: MEG recording and processing

- 306-channel MEG "Vector View" system (Elekta Neuromag).
- TSSS and SSP
- T1-weighted MRI slices on a 1.5 T Siemens scanner
- Source estimation: unsigned cortical-surface-constrained L2-norm-based minimum norm estimation by using the MNE software suite (Hämäläinen & Sarvas, 1989)
- Threshold-free cluster enhancement (TFCE) (Mensen & Khatami, 2013) in combination with permutation statistics
- Maximal temporal cluster size correction based on the approach of Nichols & Holmes (2002) with permutation statistics

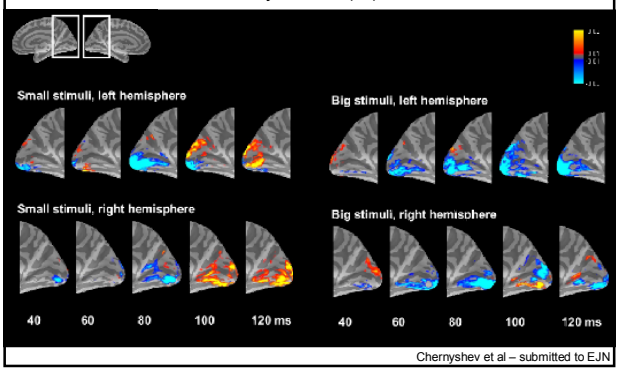
Chernyshev et al – submitted to EJN

Gradiometer RMS absolute amplitudes averaged over occipital sensors. (A) Grand-averaged timecourses of RMS absolute amplitudes for small and big stimuli. (B) RMS absolute amplitudes averaged over 40-120 time window.



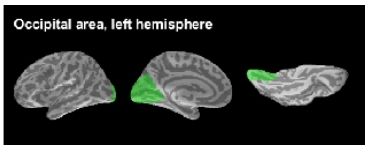
Chernyshev et al – submitted to EJN

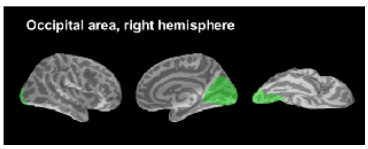
Difference in the absolute source strength between Kanizsa and control stimuli plotted on the medial occipital aspects of the inflated brain surface (grand-averaged). Negative values depicted in blue correspond to the inverted illusory contour (IC) effect. Scale: nA.



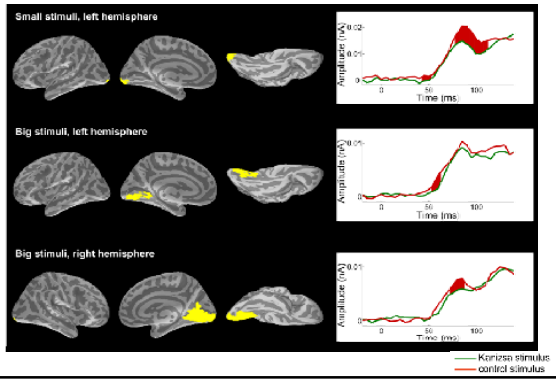
Chernyshev et al – submitted to EJN

The occipital area used to assess the inverted IC effect in source space





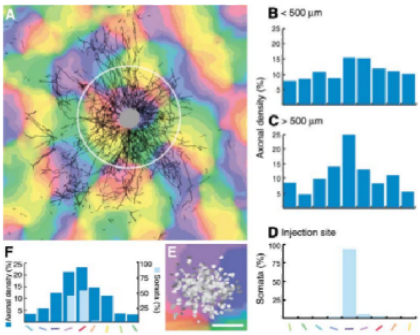
Source localization of the illusory contour (IC) effect. The regions of interest (ROIs) defined on the basis of permutation of TFCE-corrected statistics and grand-averaged timecourses of brain activity within corresponding ROIs.



Summary of main findings

- The inverted IC effect is present both at sensor and source levels
- It is present for two stimulus sizes with differing eccentricity of the IC
- It is localized in the primary visual cortex differently for the small and big stimuli in good agreement with the stimulus eccentricity.

Long-range synaptic connections within V1 may provide the basis for detection of collinearity, although feed-back influence is also possible



Stettler et al 2002

The physiological sense of surround suppression induced by collinear visual objects

- Efficient, "sparse" coding (Series et al., 2003)
- Information maximization principle (Zhu and Rozell, 2013)
- Surround facilitation by cross-oriented stimuli may be a mechanism to emphasize junctions and corners of geometrical shapes (Jones et al., 2002)
- This mechanism likely comprises an important initial stage in shape recognition, providing an informationally effective code of the retinal image suitable for further analysis. The critical step of object recognition per se is known to primarily involve LOC (Brighina et al., 2003; Murray & Herrmann, 2013; Shpaner et al., 2013).

The study was performed on the premises of Moscow MEG-center

Contributors:

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Thank you for your attention!