

VISION SCIENCE AND PSYCHOLOGY APPROACH TO ADAPTATION PROCESSES LIED IN BASE OF VISUAL ILLUSIONS

Prof. Maris Ozolinsh

Mag. Didzis Lauva

Olga Danilenko

University of Latvia, Riga, Latvia

Abstract:

We have experimentally studied visual adaptation processes and compared results in various visual perception tasks. Adaptation stimuli were demonstrated on computer screen and differed each from other by their luminance, colour, duration and dynamics related to the excited retinal and consequently the cortex neural cells and corresponding visual areas. Depth and characteristic times of adaptation processes depend on visual perception task. The slowest characteristic times (in range up to 10 sec and more) from studied processes are for adaptation to size of moving targets exciting retinal cells by equiluminant and isochrome stimuli, that are processed along parvocellular and magnocellular visual pathways. We assume that neural cell physiology lays on the base of this kind of size adaptation. Another kind of size adaptation where retinal cell excitation is static realizes in Ebbinghaus illusion. Here parallel to ongoing adaptation process brain uses also previously acquired knowledge to make shift in decision about stimuli size, and physiological effects dominate over psychological effects in perception of such stimuli. Over- or underestimating sizes in Ebbinghaus illusion with non-moving stimuli realizes much faster, and the degree of perception errors practically does not depend whether magnocellular or parvocellular visual pathway are activated – contrary to adaptation to dynamic moving targets.

Key Words: Perceptive fields, visual illusions, magnocellular, parvocellular pathways, processing of colour signals

Introduction:

Human brain processes inputs from our senses in very smart manner including modifications of deduction according to feedbacks in the sense pathways or to our previous experience. Typical example of such modification in higher level of perception is Ebbinghaus visual illusion. Here we percept the size of central disk surrounded by a number of larger disks as less sized compared to same size disk surrounded by smaller disks. It is interpreted as “top-down” process when we give attributes to details that is based on simultaneous view of a total scene. Human brain exposes to processing in cortex different kind of information entering all kind of sensory modalities.

We discuss in the present paper some aspects of processing of visual inputs. It is a very interesting case of modality processing, due to its multistage nature: on the retinal level, afterwards processing within LGN - *lateral genicular nucleus* level, finally - on cortex visual areas. Processes in these stages are based on different physiological interactions, therefore having broad spectrum of characteristic times (Rinner and Gegenfurtner, 2000; Fairchild and Reniff, 1995; Shevell et al., 1999). Adaptation to luminance and colour, adaptation to stimuli colour contrast and colour purity, and adaptation to stimuli size and form are within variety of these processes. Adaptation is forwarded to more economic expenses in neural activity - to increase the dynamical range of modalities, and to elimination of sensation “errors” of different origin with help of previous experience. That leads to aftereffects and oft to deliberate sensation faults. They can cause so-called visual illusions (see: <http://michaelbach.de/ot/> ; Bach, 2013). All spectrum of visual illusions is enormous. The aim of present paper is to analyze some selected and recently mentioned in literature effects allowing to make some conclusions on the way of interpretation of effects mainly on the base of the phenomena characteristic times.

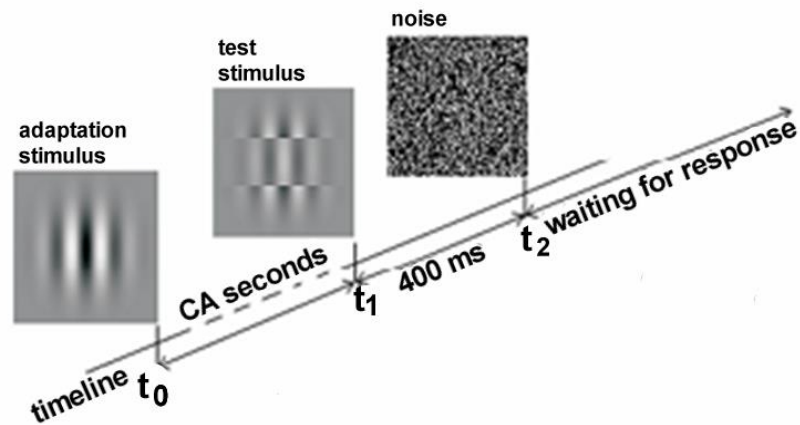


Fig. 1. Time sequence of adaptation to stimulus contrast experiment.

Main Text:

Further we describe and give the relevant details of following experiments of our current and published studies: a) of colour and colour contrast adaptation (Lauva and Ozolinsh, 2008); - b) of colour purity adaptation (Karitans and Ozolinsh, 2012), - c) of dynamic size adaptation and comparing these results with the Ebbinghaus effect (Danilenko and Ozolinsh, 2013). All effects were studied quantitative by constant stimuli psychophysical method using multi-alternative force choice AFC paradigm. In all these cases the method consists of repetitive sequences of number of phases: adaptation phase, blanking phase, response phase, relaxation phase. During adaptation phase with variable duration the visual target is divided in parts - the left (or right) visual field with the target to adapt and the central fixation point of gaze. Blanking phase served as a variable duration pause to delay the observer response instant respectively to the end of adaptation. During the last phase in both – the left and right visual field the comparison stimuli were demonstrated, and the observer was obliged to make his response choice. The number of trials were sufficient to build psychometrical curve which allowed to approximate data with sigmoid (mainly), to obtain the curve centre shift and slope. Such way gave the advantage to minimize the objective perception hysteresis effects, to avoid subjective decision shifts, but it was a method of considerable time wasting. The latter restricts areas of application of the method due to observers' fatigue.

In the first series of demonstrations we studied the time dependence of contrast of colored Gabor gratings (Lauva and Ozolinsh, 2008). The adapting stimuli were Gabor gratings of spatial frequency 1deg with different Michelson contrast (Fig.1). During adaptation phase the perceived contrast amplification in observer cortex diminishes. That can be interpreted as inducing of a negative aftereffect that is added to the positive adaptation stimulus. The stimulus during the response phase consists of compound areas – areas of two side stimuli with unchanging high contrast reference gratings (inphase with adapting stimulus), and the central test area of control grating with variable contrast counterphase grating. Observer task is to choose between two choices – is the perceived grating in central test area in-phase with two lateral reference gratings (that fulfills if compensation stimuli contrast is overestimated) or it is counter-phased (compensation stimulus contrast underestimated). Psychometric function symmetry center reveals the aftereffect contrast value. Fig.2 shows the time dependence of the negative retinal+cortical aftereffect measured immediately after switch of the adapting stimuli. The relationship in the measured time range obeys well the exponential law with characteristic time $\tau = 4.6$ sec. Colour vision adaptation processes are studied previously (Shevell, 1999; Werner and Walraven, 1982). We found a similar time course, well fitted to exponential law, for vision adaptation to colour saturation. Experiments were built (Karitans and Ozolinsh, 2012) on the constant stimuli trial paradigm, using two-choice AFC method. Colour purity adaptation time had characteristic time $\tau = 0.8$ sec. It is less than measured adaptation time constant

for contrast amplification for the same person. However it can be marked, that distribution of characteristic times can be broad and diffused. But colour purity adaptation occurs without spatial resolution and therefore it is very prospective to have longer characteristic time for adaptation of spatial frequency dependent image contrast adaptation in brain.

Dynamical adaptation to stimuli geometrical features was studied in the following way. An observer gazes at the point situated in the central vision area while in one of the vision fields – in the left (or right) field a number of disks are randomly moving around for a fixed adaptation time interval. After that the control stimulus is demonstrated for a short time interval. The control stimulus consists of two smaller disks located symmetrically to the screen centre and one of the disk - in the centre of the adaptation area. The observer task is to make his choice which of these disks (in the left or right vision field) has larger diameter. For duration of adaptation phase – 15-20 sec, the observer perceives the control stimulus at the visual field of adapting stimuli of size smaller than in the previously “blanked” visual field (Fig.3).

Such size adaptation in dynamical viewing conditions was reported previously (Baker and Meese, 2012). We have studied the effect of size adaptation more detailed and quantitative. The shift in perception of disk sizes depends on adaptation phase duration and on diameters of disks in the visual field of adaptation. The strength of adaptation depends also on the colour of stimuli or more precise – on the colour contrast of stimuli and surrounding ΔK .

Stimuli in this experiment were chosen to activate either colour sensitive M magnocellular or luminance sensitive P parvocellular neural pathway (including stages in LGN *lateral geniculate nucleus* and in cortex). Inputs to M pathway are provided by neural cells located in peripheral retinal area. Corresponding neural receptive fields are relative large and neighboring receptive fields are overlapping each other. Inputs to P pathway are provided by neural cells in the central retinal area and corresponding neural receptive fields are smaller. There is a difference between signal speed of M and P pathways' neural activity transfer. Actually adaptation depends very seriously on the complexity of neural interconnections and of neural cell chemical processes. Moreover the size and form adaptation is determined by neuronal cell interconnections and their rearrangement during adaptation phase – a typical example of that is binocular fusion of two eye images within the retinal Panum's fusional area.

On the premise that all neural activities are going either within P or M pathways one would

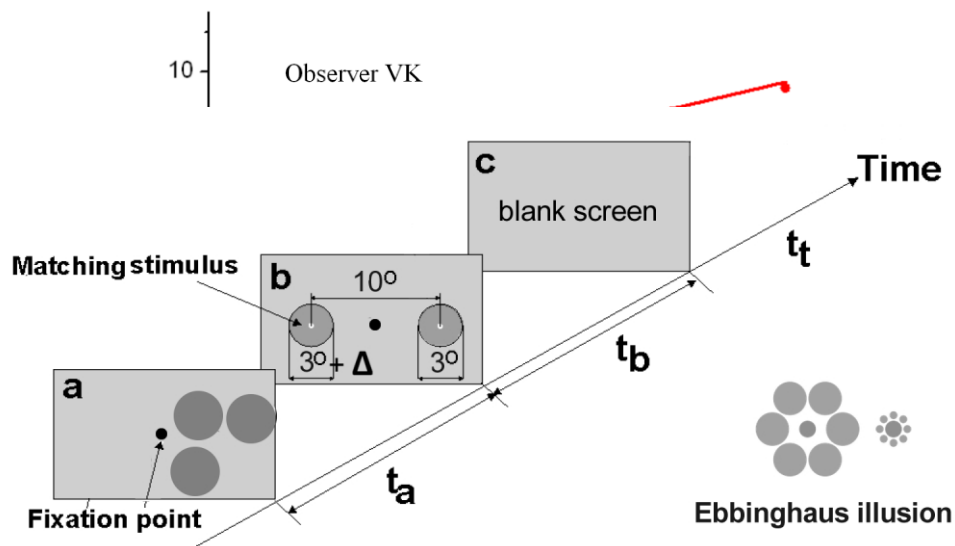


Fig. 3. Scheme and time course of experimental studies of dynamical size adaptation with moving around adaptation stimuli on screen **a** (t_a and t_b – adaptation, and subjects response phases, respectively). Insert in left corner shows Ebbinghaus illusion used for size adaptation comparison when activated retinal area is dynamically changing and is static as in Ebbinghaus illusion case.

predict a difference in: strength of illusion, firstly; and time of adaptation, secondly (for both cases - either stimuli are equiluminant or isochromatic).

Results of dynamic size adaptation revealed that the strength of adaptation of isochromatic (activation of M inputs) stimuli is stronger comparing to adaptation of equiluminant stimuli. The adaptation differs by factor 1.4 when comparing two “background-stimuli” pairs: brighter gray and darker gray (located along central vertical axis of $L^*a^*b^*$ color space) pair and reddish-greenish (placed horizontally in $L^*a^*b^*$ color space) pair. Pairs’ stimuli mutual color contrast $\Delta K = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$ was kept constant. This size adaptation process also obeys to exponential law and has the characteristic time τ longer than characteristic time for adaptation processes where is no need to spatial adaptation. Fig.4 shows adaptation time course for red-green case.

The mentioned previously experiment where adaptation happens in time range of measurement method was compared with similar size adaptation to static target – Ebbinghaus effect (Roberts et.al., 2005; van Ittersum and Wansink, 2012). Here the within the size adaptation process brain uses also previously acquired knowledge to make shift in decision about stimuli size. In all previously described cases the physiological effects dominate over psychological, comparing two disks with different surrounding – number of smaller or larger disks located symmetrically to the center of symmetry. Ebbinghaus illusion induces sense of relative increase of the size of disk with number of smaller surrounding disks. In our experimental trials the observer should evaluate the size of variable central disk surrounded by larger diameter outer disks, comparing it with constant size central disk of neighboring set of disks.

It was prospective that during this variation of Ebbinghaus effect neurons in the brain visual areas still underwent considerable connectivity reorganization, that will lead to time dependent induction of shift in size evaluation during adaptation.

Results reveal notable difference in adaptation character. Firstly adaptation is much stronger comparing to adaptation to moving stimuli without surrounding. Fig.5 shows comparison of the psychometric curves of the perceived disk size shift for experiments with dynamic moving adaptation

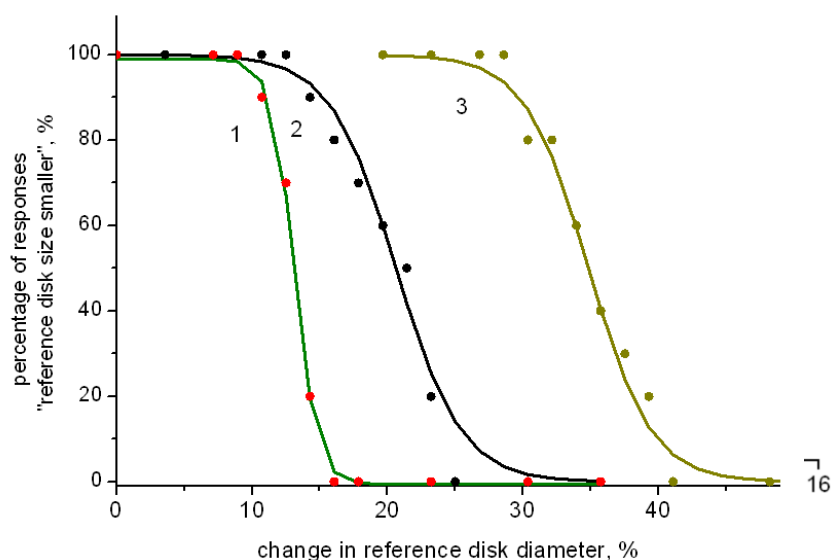


Fig. 5. Psychometric curves obtained for experimental trials of decreasing of perceived test disk size after adaptation to larger dynamical moving stimuli (equiluminant colour stimuli – curve 1, isochrome stimuli – curve 2) and increasing of perceived test stimuli size after adaptation to Ebbinghaus illusion stimuli (curve 3).

stimuli (curves 1 and 2) and for static central disk in Ebbinghaus effect (curve 3). The perception shift in the latter case is doubled. Secondly, adaptation occurs almost momentarily, taking into account time resolution of experiment. No remarkable time course is observed in evaluation of disk size in the time range of experiment.

Conclusion:

We conclude that input to magnocellular visual pathway dominates over parvocellular input in size adaptation to dynamically moving adaptation stimuli. Time dependence of this adaptation is slower comparing with adaptation processes when spatially resolved activation of retinal and cortex neural circuits is minimized – f.e., static colour purity, retinal and cortex contrast amplification. We assume that in these cases physiological effects in neural cells dominate over psychological effects. Perception of disk sizes (both in equiluminant and isochromatic condition) in Ebbinghaus visual illusion in its turn reveals: stronger effect, much faster adaptation, weaker dependence on stimuli color and contrast. We hypothesize that dynamic size adaptation lays at visual areas much earlier than perception processes in Ebbinghaus illusion, that can be held as “top-down” perception case.

Authors have been supported by the ESF and ERAF foundations.

References:

- Bach, M. (2013), “103 Visual Phenomena & Optical Illusions”. <http://michaelbach.de/ot/>.
- Baker, D.H. and Meese, T.S. (2012), “Size Adaptation Effects are Independent of Spatial Frequency Aftereffects”, *Perception* 41, p.S33.
- Danilenko, O. and Ozolinsh, M. (2013). “Size Adaptation Effect”. *Proc.DOC-2013*, Riga: University of Latvia, pp.146-147.
- Fairchild, M.D. and Reniff, L. (1995), “Time Course of Chromatic Adaptation for Color Appearance Judgments”. *J. Opt. Soc. Am.* A12, pp.824-833.
- Karitans, V. and Ozolinsh, M. (2012), “Dependence of Perceived Purity of a Chromatic Stimulus on Saturation Adaptation”. *Medicina*, 48 (9), pp.458-464.
- Van Ittersum, K. and Wansink, B. (2012), “Plate Size and Color Suggestibility: The Delboeuf Illusion’s Bias on Serving and Eating Behavior”. *J.of Consumer Research* 39(2), pp.215-228.
- Lauva, D. and Ozolinsh, M. (2008), “Neural Interaction of Retinal Aftereffects and Contrast Adaptation in Perception of Gabor Gratings”. *J.of Vision*, 8(17), p.73.
- Rinner, O., Gegenfurtner, K.R. (2000), “Time Course of Chromatic Adaptation for Color Appearance and Discrimination”. *Vision Research* 40, pp.1813–1826.
- Roberts, B., Harris, M.G., and Yates, T.A. (2005), “The Role of Inducer Size and Distance in the Ebbinghaus Illusion”. *Perception* 34(7), pp.847–856.
- Shevell, S.K. (1999), “The Time Course of Chromatic Adaptation”, *Color Research & Application* 26, pp.170-173.
- Werner, J.S. and Walraven, J. (1982), “Effect of Chromatic Adaptation on the Achromatic Locus: the Role of Contrast, Luminance and Background Color”. *Vision Research* 22, pp.929-943.