



Low vision and brain plasticity

Chair: Bernhard A. Sabel, PhD

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Bernhard Sabel, PhD, is world expert and practitioner of vision restoration techniques. He is a professor on the Medical Faculty of the Otto-von-Guericke University of Magdeburg and director of its Institute of Medical Psychology in Magdeburg, Germany. He is a neuroscientist and psychologist who trained at Clark University in Worcester/Massachusetts and at M.I.T. in Cambridge, USA and held research scientist positions at Harvard Medical School, Princeton University, and at the University of Munich. Since 1992, Prof. Sabel has been developing non-invasive vision restoration techniques to improve the eyesight of victims of stroke, brain trauma, optic nerve damage, and eye diseases such as glaucoma and diabetic retinopathy. The techniques include rehabilitation training and noninvasive electric brain stimulation using a brain pacemaker. Prof. Sabel is editor-in-chief of an international journal of brain repair and plasticity, *Restorative Neurology and Neuroscience* (IOS Press, Amsterdam, The Netherlands). He has received international awards for his work on vision restoration techniques, including *Cinquegrani–Award* for best innovation in information and communication technologies, *Leonardo DaVinci–Award*, *High-tech start-up award*, German National Minister of Economics, and the *"Hai-ju" Award*, Beijing Overseas Talents Program from the city of Beijing/China. Prof. Sabel is a member of the executive committee of the International Society for Low Vision Rehabilitation and Research (ISLRR) and a member of the governing board of the International Brain Injury Association (IBIA). He is author of the recently monograph *"Restoring Low Vision"* published by AMAZON.

Symposium abstract

In the past decade numerous studies have crossed the traditional boundaries between a 'peripheral' and 'central' visual system. There is growing evidence that ocular diseases may have cerebral consequences and that consequences of neurological diseases may be seen at the ocular/retinal level. One clinically important example highlighting the role of the brain is neuroplasticity which refers to our brain's life-long ability of adaptation to different circumstances such as during learning or after CNS damage. This plasticity, measurable by the brain's potential for perceptual learning and reorganization, offers new opportunities for rehabilitation. On the other hand, functional reorganisation of the visual pathway does not necessarily mean automatic improvement or recovery of function, and some forms of plasticity may even hamper recovery. A most pronounced case of plasticity is transmodal plasticity. When vision is lost, other sensory modalities may take over visual cortex tissue and thus strengthened other senses such as hearing and touch. In this symposium recent studies on low vision and brain plasticity are presented in light of their potential for perceptual learning, functional recovery and restoration/ rehabilitation.

Symposium Presenters & presentation titles:

1. Michelson, Georg (Germany): Visual Perceptual Learning Improving Stereovision: Repetitive Dynamic Stereopsis Training Over Six Weeks Improved Recognition Speed of Stereoscopic Stimuli
2. Vaucher, Elvire (Canada): Cholinergic potentiation of the visual system: implementation to visual rehabilitation
3. Ladavas, Elisabetta (Italy): The role of the retino-colliculo-extrastriate pathway in visual awareness and visual field recovery
4. Sabel, Bernhard (Germany): Restoring low vision by brain functional network synchronization

1. Visual Perceptual Learning Improving Stereovision: Repetitive Dynamic Stereopsis Training Over Six Weeks Improved Recognition Speed of Stereoscopic Stimuli

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Background: Visual perceptual learning was shown to improve the stereo threshold in patients with impaired stereovision by repetitive visual function tests. Stereo acuity and response time are important parameters to characterize stereopsis.

Methods: 25 young male subjects performed twelve sessions of a 15 minute repetitive dynamic stereopsis training over six weeks. One training session consisted of 400 trails heading to 4800 trails overall. The dynamic stereo training (c-DIGITAL VISION TRAINER®) provided moving stereoscopic stimuli presented on a polarized 3D-TV in a four-alternative forced choice setup. We measured the response time of correct identified visual tasks of 11, 22, 44, 55, 66, 77 and 88 arcsecs disparity before, after six sessions, after twelve sessions and after six months without testing. The response time is the sum of recognition time plus the motoric response time. As the response time increased with decreasing disparity, we defined the difference between response time at 11 and 88 arcsecs as recognition time for 11 arcsecs.

Results: After 2400 trails with the repetitive dynamic stereopsis training over 6 weeks recognition time at 11 arcsecs decreased significantly from 804ms to 350ms. After six months without training the response time at 11 arcsecs remained at the level of the last session.

Conclusion: Our data suggests that training of stereopsis by c-DIGITAL VISION TRAINER® significantly and enduringly improved response and recognition time. The good retention indicates the longevity of perceptual learning.

2. Cholinergic potentiation of the visual system: implementation to visual rehabilitation

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Introduction: The cholinergic system is a potent neuromodulatory system which plays a critical role in cortical plasticity, attention and learning. Recently, it was found that boosting this system during perceptual learning robustly enhances sensory perception. Especially, pairing cholinergic activation with visual stimulation increases the signal-to-noise ratio, cue detection ability and long-term facilitation in the primary visual cortex. The mechanisms of cholinergic enhancement are closely linked to attentional processes, long-term potentiation and modulation of the excitatory/inhibitory balance. Here we examined whether the activation of the cholinergic neurons could help visual rehabilitation.

Methods: Different studies have been done to show how pharmacological enhancement of the cholinergic system with inhibitors of acetylcholine esterase paired with visual training increased visual learning in the rat and human and restoration of visual capacities in rodents following a visual deficit induced by partial optic nerve crush.

Results: The training regimen coupled to cholinergic stimulation did influence neuroplastic and functional changes in the primary visual cortex in rats and visual learning in humans.

Conclusion: Potential therapeutic outcomes ought to facilitate vision restoration with commercially available cholinergic agents combined with visual stimulation in order to prevent irreversible vision loss in patients. This approach is thus promising to help a large population of low vision people.

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3. The role of the retino-colliculo-extrastriate pathway in visual awareness and visual field recovery

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The aim of our research is to study the role of the visual cortical and subcortical pathways on the visual processing in hemianopic patients and healthy participants. Evidence on hemianopic patients showed that a lesion to or deafferentation of the primary visual cortex prevent the conscious visual processing of any attribute of the stimuli presented in the blind field. However, salient unseen stimuli, presented in the blind field, can enhance the visual processing of stimuli presented in the intact field, both at the behavioural level and at the electrophysiological level. This can be probably due to an alternative visual pathway, which projects from the superior colliculus to the extrastriate cortex, which is usually spared in patients with visual field defects. Evidence for spared function of this alternative pathway in patients with visual field defects will be presented, both in terms of residual visual abilities,

without awareness, for stimuli presented in the blind field, and of the ability to integrate unseen visual signals presented in the blind field with concurrent auditory stimuli. Crucially, we will discuss how the spared retino-colliculo extrastriate pathway might be a useful tool for compensating the loss of visual perception. Accordingly, evidence for the compensatory effects of systematic multisensory audio-visual stimulation in patients with visual field defects will be reviewed.

4. Restoring low vision by brain functional network synchronization

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Visual field defects are considered irreversible because the retina and optic nerve do not regenerate. Yet, there is some potential for neural repair and recovery of the visual fields. This is accomplished by the brain which analyses and interprets visual information and is able to amplify residual signals through neuroplasticity.

Neuroplasticity refers to the ability of the brain to change its own functional architecture by modulating synaptic efficacy which is maintained throughout life. The question now arises how plasticity can be utilized to activate residual vision for the treatment of vision loss.

Just as in neurorehabilitation, visual field defects can be modulated by post-lesion plasticity to improve vision in glaucoma, diabetic retinopathy or optic neuropathy. Because almost all patients have some residual vision left, the goal is to strength residual capacities by enhancing synaptic efficacy. New treatment paradigms were tested in clinical studies, including vision restoration training and non-invasive alternating current stimulation. While vision training is a behavioural task to selectively stimulate “relative defects” with daily vision exercises for the duration of 6 months, treatment with alternating current stimulation (30 min. daily for 10 days) activates and synchronizes the entire retina and brain.

Though a full restoration of vision is not possible, such treatments improve vision both subjectively and objectively. This includes visual field enlargements, improved acuity and reaction time, improved orientation and vision related quality of life. About 70% of the patients respond to the therapy and there are no serious adverse events.

Physiological studies of the effect of alternating current stimulation using EEG and fMRI reveal massive *local* and *global* changes in the brain. This includes local activation of visual cortex and reorganization of neuronal brain networks.

Because modulation of neuroplasticity can strengthen residual vision, the brain deserves a better reputation in ophthalmology for its role in visual rehabilitation and for patients there is now more light at the end of the tunnel of vision loss.