Dr. Udo Ernst
Bernstein Award Recipient 2010, Institute for Theoretical Physics,
Department of Theoretical Neurophysics, University of Bremen

Dr. Ernst, could you please explain what your research says about how we see the world?

One of the most important insights from years of research on human vision is that visual perception is an extremely difficult problem. Our brain analyzes visual scenes so efficiently that we often don't even realize that it requires complex computations: in fact, visual scenes are processed by millions of neurons, each of which has access to only a small portion of an image. These distributed, tiny chunks of information must be assembled in order to perceive objects and to make sense of our world. To simplify this computational problem, the brain uses many "dirty" tricks. One is to ignore those parts of a scene that are irrelevant for the current behavioural goal, and to put all computational resources on the remaining part of the visual input ("selective attention"). This happens all the time, and consequently, we are virtually blind to most aspects of visual stimuli, except when our attention - either intentionally or by chance - is directed to a certain aspect. There are nice demonstrations of such effects like the famous "change blindness," which are very surprising because our brain usually lets us believe that we are aware of everything we see.

Is there a way to enhance perceptual ability?

Yes, and there are different aspects to this question. In principle, the brain enhances and suppresses perceptual abilities all the time. This process is termed "parallel functional configuration." Not unlike a computer that runs different software on the same hardware, we think that the brain rapidly reconfigures its processing of visual information to perform as well as possible in the current situation. Of course, this enhancement has its limitations: not every task can be performed equally well, and while some abilities are enhanced, others might be severely suppressed, as mentioned above. Functional configuration is barely understood, and my current research aims at uncovering its underlying principles and mechanisms.
In addition to these fast "switching" processes, the brain also *learns* to perform better in a given situation, but on a slower time scale. Through perceptual learning, humans might increase the temporal or spatial precision with which they perceive visual stimuli. A prominent observation from psychophysical experiments is that subjects who regularly play computer games tend to be more rapid and more efficient in perceiving fast changes in a visual stimulus.

How do factors, such as context, knowledge, and intention influence visual processing in the brain? Which of these factors is the most influential?

This depends on the situation. All of these factors influence perception to varying degrees. Imagine a busy street scene on one of New York's boulevards: When looking for a specific person, our brain focuses on the typical features of that person, e.g. their hair color, body height, and preference for clothing. Here knowledge "controls" visual processing. On the contrary, when intending to cross the street, visual processing will more strongly use contextual information: a roaring sound from the right, or a fast movement in the periphery of the visual field helps the visual system to quickly decide whether cars are advancing, or whether they are leaving a gap for safely reaching the other side.

In your opinion, can vision be restored or relearned? What role can the cortical visual prosthesis play in restoring vision?

In principle, adaptability and plasticity of cortical processing make it possible that one part of our visual system can partially compensate for the loss of functionality in another part. Thus adequate training procedures could, for example, help stroke patients who suffer from a partial impairment of their visual capabilities. However, to devise suitable rehabilitation strategies, we must know more about how flexible the visual system is, which aspects of its functionality can be restored, and how the intact brain areas can best be trained to operate towards this goal.
In contrast to this idea, a cortical visual prosthesis pursues a different goal. Their basic idea is to use signals from the visual system to help paralyzed patients to interact with their environment and reestablish communication with other persons. One example of such a brain-computer interface (BCI) is the visual typewriter: an alphabet is displayed on a computer screen and the user of the BCI then attends to one particular letter. The information about which letter the subject selected is then extracted from the brain signals and used, for example, to write an e-mail.

Could you please share your plans to further develop the visual typewriter?

On current visual typewriters, the letters on the screen flicker at different frequencies. The frequency of the letter which a subject selects becomes imposed in his/her brain waves. The BCI application then tries to identify this frequency in the recorded brain activity and types the corresponding letter.
To improve this kind of a typewriter, we now want to directly decode the screen position of the letter selected by the user without requiring the stimulus to undergo a fatiguing flickering sequence. Using data from the lab of our colleague, Prof. Andreas Kreiter, we have been able to extract this information from local field potential recordings in macaque monkeys. In particular, we achieved a high decoding performance with up to 99% accuracy. We are convinced that this novel approach, with its high speed, reliability, and robustness will have great value for future BCI applications - especially in conjunction with the new wireless recording technologies that are currently developed in the Kalomed project funded by the BMBF.