We started by not knowing what the meeting set out to discuss, which had the excellent effect of freeing us from preconceptions. Sharing the unknown was an enjoyable, exciting adventure. Like being born again, though able to speak and listen.

Ivan Bodis-Wollner’s definition of pre-emptive: “neurobiological processes which cover the time period before an action is initiated up to the time it is completed” (see his Introduction, overleaf) proved helpful. One might think of it as so general it includes all of perception and all behaviour, but (if perhaps by his persuasive charm) it set up an excellent meeting we are all likely to remember. Surely this emerges from the papers in this special issue, so pre-emptive is fulfilled.

Richard L Gregory

Note: All authors had an opportunity to amend and edit their papers for publication in this special issue.
Introduction

Recent advances in signal analysis, and in technical, instrumental, and psychophysical methods make it possible to experimentally approach classical questions of epistemology. We are now in the position to dissect fine temporal segments and functional anatomical differences of neurophysiological events occurring before, during, and after action.

The term pre-emptive perception (PEP) refers to neurobiological processes which cover the time period before an action is initiated up to the time it is completed. An essential aspect of PEP is provided by studies which reveal neuronal mechanisms which select an action prior to a perceptual identification of the intended goal, at the expense of other possible actions. The papers in this issue of *Perception* attest that the term PEP has neurobiological footing and provides heuristic usefulness for neurobiologically driven epistemology.

This issue of *Perception* is based on an interdisciplinary conference on Pre-Emptive Perception organized in 2005 at the Hanse Institute for Advanced Studies in Delmenhorst, Germany. The aim of the conference was to gather together what was then known about brain activity prior to and during action in order to determine if the new term ‘pre-emptive perception’ has validity. This issue is not simply a volume on conference proceedings: it presents an examination of the concepts and science embedded in the term PEP. Most papers have been revised by the authors for publication in this issue.

While the concept of PEP is applicable to reaching and grasping and withholding movements, in this issue there is a greater number of studies involving saccadic eye movements. Saccades provide the possibility of more precise temporal subdivision of neuronal processes linked to action.

The contents of this issue are organized into four sections: the two phases of PEP, neuronal mechanisms that may contribute to PEP, and the relation of PEP to enactive perception.

**Neuronal mechanisms beginning in the first phase of PEP**

A fundamental mechanism of the first phase of PEP is the selection of one specific and goal-directed action at the expense of all others. All other movements are pre-empted by the correctly selected action. Prior to action, the perceptual or behavioral relevance of the intended action determines the selected response.

1 *Intrinsic mechanisms and the selection of action and subsequent perception*

Perceptual identification does not necessarily determine the form of an action. In fact, an action is often selected in the absence of an immediately preceding input. In the real environment, the number of ‘distractors’ is immense, basically the whole scene. The number of possible computations of one ‘trained’ cell group versus all others is formidable. How is this process optimized? What influences exert themselves before the winning neuronal group is selected? The selection may be based on context. The effect of prior visual context on subsequent reaching is shown in monkey inferotemporal (IT) neurons before targets are selected. *Rolls* discusses electrophysiological studies in IT which reveal context-linked pre-emptive determinants of both eye movements and reaching. He shows that in selecting the winners the pre-emptive bias in IT is a functional-anatomical constraint imposed by the preferential role of the fovea.
Using experimental psychological and imaging methods, Goodale, Gonzalez, and Kröliczak provide evidence that task definition has a dissociative effect on grip size and an anatomical separation of pathways exists; one is for perceptual judgments of illusions, the other for adjusting the size of the grip. What these studies demonstrate in reference to PEP is that the internal context (task instructions) to the subject determine the specifics of the response and preclude the alternative.

Transcranial direct-current (TDC) stimulation studies by Antal and Paulus show that setting the gain of visual neuronal groups affects subsequent target detection. They propose that, preceding perception, local gain of the underlying neuronal circuitry is affected by TDC. They consider that, in order to change local gain, a reorganization of the primary visual cortex may occur via both local and long-ranging connections. Studies by Amassian, Mari, Sagliocco, Hassan, Maccabee, J B Cracco, R Q Cracco, and Bodis-Wollner suggest that a ‘thalamic gate’ is involved in enhancing subsequent visual cortical processing from frontal to occipital cortical areas.

2 Timing in relation to the intended goal of the action
Presaccadic computations of lateral inferior parietal (LIP) neurons reveal some quintessential aspects of PEP. Gee, Ipata, Gottlieb, Bisley, and Goldberg show that, when the monkey is taught a memory-guided saccade away from the receptive field of a LIP neuron, the abrupt onset of a ‘distractor’ has no effect on the saccade itself, but it does have a brief (some 100 ms) effect on diversion of attention to the distractor. The relative activity of the ‘target’ and ‘distractor’ population determines the performance: ie either an appropriate memory saccade or an appropriate maintenance of fixation. Reconfiguring the activity map is apparently achieved by shifting the weight among competing neuronal groups. These studies show that and when the losers are ‘pre-empted’ by the winners.

The minimal mechanism by which a single neuron, or small number of neurons, can give advance notice and gain time for pre-emption is shown and formalized in a model by Lytton, Orman, and Stewart. Their model reveals a neuronal mechanism which allows the prediction of the presence of a target, calculating it, and identifying it in detail in the shortest possible time. Considerable time would be lost, as much as 100 ms, if there were no pre-emptive vision and the brain had to wait for processing a desired action.

The second phase of PEP
The second phase of PEP starts when neuronal mechanisms identify the beginning of an action and finishes when that action reaches the target. Several papers in this issue consider neuronal mechanisms of on-line monitoring of action prior to completion.

3 Neuronal circuits
Studies in the monkey reveal the functional anatomy of the corollary discharge (CD), the signal that provides advance information to sensory cortices (Sommer and Wurtz). The concept of CD is axiomatic for PEP. The pivotal anatomical element of CD is the superior colliculus. It is an active participant in the flow of commands between the frontal and parietal cortices.

Studies in humans show that, in the absence of visual input, there is modulation in the strength of neuronal synchronization (gamma oscillations) over the posterior cortices before, during, and following voluntary saccades. Forgacs, Gizycki, Selesnick, Syed, Ebrahim, Avitable, Amassian, Lytton, and Bodis-Wollner propose that, during the second phase of PEP, intrasaccadic neuronal synchronization in humans is reflected in the gamma component of the surface-recorded EEG.
**4 PEP and enactive perception**

While some concepts of PEP and enactive perception (EP) are related, PEP and EP are categorically divisible. The characteristics that distinguish PEP from EP are discussed in two papers, one by Jacob and one by Schumacher. Each of these considers available perceptual/motor behavioral experimental evidence from infant development. Toddlers’ action to illusory sizes seem to indicate that perception and action are dissociable (as shown by Goodale et al. in adults). Jacob and also Schumacher discuss cardinal differences between PEP and the theory of EP, as admirably argued by Noe (2004). Bodis-Wollner discusses the neurophysiological rationale for a temporal subdivision of PEP into two time segments, one preceding and the other during a saccade. The first phase of PEP includes neuronal processes which relate to an intention to act and determine a specific and selective action. The second phase of PEP pertains to ‘on the fly’ processes of the action. Bodis-Wollner proposes a heuristic usefulness of the temporal subdivision of PEP. In the context of PEP a temporal distinction can be made between neuronal mechanisms of *Intention* and *The Will* (in the sense of A Schopenhauer). Because of this experimentally approachable distinction he suggests that ‘The Will’ can be neurobiologically studied within the framework of PEP.

**Acknowledgments.** The conference workshop ‘Pre-emptive Perception’ took place in October 2005 at the Hanse Institute for Advanced Study in Delmenhorst, Germany. It was chaired by Gerhard Roth, Rector of the Hanse Institute, Manfred Fahle from the University of Bremen, and Ivan Bodis-Wollner, State University of New York, Downstate Medical Center, and Fellow of the Hanse Institute. The support of the Hertie Foundation and the Hanse Wissenschaftskolleg (HWK) made it possible to organize the conference. The staff of HWK, and in particular Dr Wolfgang Stenzel, provided vital support and organization of cultural and social events. Ewart Kramer helped to organise a musical interlude, where participants had to identify a short segment by the music. A clue was the relevance to PEP as the musical segments represented (subjective) time before action. The puzzle was solved by Mickey Goldberg. Conference speakers were invited from Canada, France, Germany, the United Kingdom, and the United States. The broad disciplines represented were experimental neurophysiology, neuronal modeling, experimental psychology, and epistemology. The invited speakers were Vahe Amassian, Andrea Antal and Walter Paulus, Mickey Goldberg, Mel Goodale, Richard L Gregory, Pierre Jacob, William F Lytton, Edmund Rolls, Ralph Schumacher, and Bob Wurtz. Posters were selected from junior faculty and graduate students from various universities. From these, three were selected for oral presentation and discussion with a ‘faculty’ member (one of the conference speakers who volunteered before the conference) acting as *opponent* and by the audience. A strong impetus for the conference was to foster interdisciplinary dialogue. At the beginning of the conference many participants questioned what the term PEP means. This uncertainty posed a challenge to all participants and engendered many fruitful discussions.

Ivan Bodis-Wollner
Downstate Medical Center, State University of New York; e-mail: Ivan.Bodis-Wollner@downstate.edu

© 2008 a Pion publication