The transition between unconscious matters in the brain and conscious ones – volition and free will.

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My reaction to Prof. Kihlstrom is very positive. I agree with his emphasis on the importance of the unconscious. In the brain we have both conscious and unconscious processes and both are important. There are always numerous processes in our brain running in parallel and overlapping and do a lot of work we are not consciously aware of. These are our subroutines and expert systems that also are modelled by evolution. In the metaphor of an iceberg, consciousness is only its tip over the water surface, the vast majority is under water, is unconscious.

I will explain why nature had to introduce a mechanism like consciousness in the later course of the evolution. In order to render the individual capable of *acting* properly in its environment, consciousness is very restrictive. It has to be. I will give an estimate of the channel capacity (Wiener 1948) of consciousness, and we will be surprised how low it is. Between the information flow in our senses and consciousness there is a selection – of course again organized unconsciously – of the most important. It is filtering but very intelligent filtering resulting in condensing the information by at least four orders of magnitude. On the basis of a handy "stage" of events that can be overviewed – similar to a commando bridge on a ship – we remain capable of acting.

Consciousness is an essential brain function of higher animals and man, and it is a strong tool we have. It enables us – on the background of immense knowledge – to act prudently or to solve problems with a general view. It is by no means a mere epiphenomenon. A patient after brain injury who does not regain consciousness cannot – even if he survives for years – compensate his handicaps, if he wakes up out of coma into consciousness, he can learn, cooperate with the physio- and ergotherapist and partially regain lost functions, also by the help of other brain areas taking over. Our brain is an enormously complex something – it can be called the most complex 1½ kg of the universe – in which many things are tried spontaneously. What of these trials has continuance, depends on its testing in the external world. Without this permanent probation and corroboration our brain would be not manageable. The reason that our consciousness is so important is not only that it facilitates learning, choice selection and freedom of decision but also that it does not do everything alone, rather *it delegates most of the agenda to unconscious routines*. Such routines are overtrained expert systems which became available in the animal kingdom long before man. These routines work unconsciously but in case of novelty and new demands consciousness can be brought in again. To load all information processing into consciousness would mean to extremely overcharge it. That consciousness is not among the early birds but gets up later does not lessen its effectiveness – on the contrary it is sheltered against many chance processes of neuronal activity and undisturbed by false alarms by pre-establishing thresholds and filters so that it is set free for the really important matters. Thus, consciousness contributes a lot to creativity of man. Devaluation of consciousness, e.g. declaring it an epiphenomenon, is not helpful (also cf. Delacour 1997, for theory of consciousness cf. Steinbuch 1965 and Dennett 2005). So important consciousness is, it is not the only operational basis in the brain.

We are now in the position to see the experiments of Libet et al. (1983) in a new light, to be more precise their interpretation by Libet. By using the Bereitschaftspotential (BP) method (Kornhuber & Deecke 1964, 1965), Libet et al. (1983) let their subjects perform so called *introspection*. To his own

surprise, as Benjamin said, these experiments showed that the BP is not, right from the beginning, accompanied by a conscious awareness about the intention of movement. Libet´s experiments are taken by some neurobiologists to advocate a total determinism (e.g. Roth 2001, Singer 2003). In order to facilitate such introspection, Libet instructed his subjects they should by means of a clock (2,4 sec per revolution) retrospectively remember the instance at which they had the conscious sensation "now I feel the urge to move." That means subjects had to look into themselves and say retrospectively when on the clock the urge to move came over them. The result was that the readiness potential started some 300 - 400 msec earlier than the conscious awareness of the desire to move now. Libet´s *experiments* – in the meantime they have been repeated with *choice reaction*, but this has not brought new aspects – are interesting und o.k., the *conclusion* however, that he draws, is wrong. Libet thought, since the Bereitschaftspotential starts earlier than his subjects´ inner sensation "now I feel the urge to move" becomes aware to them, the initiation of the voluntary movement could not have been initiated by free will. However, this is a fallacious argument: As we have heard, much in the brain is unconscious. There is conscious and unconscious and both is important. Libet makes a mistake in thinking, or has not thought it to the end, if he believes that consciousness and will must be coupled all the time. On the contrary, Kornhuber and I think that – if the BP starts earlier than subjects' conscious feeling to wish to move – this does by no means imply that it was not our own will and intention that has inititiated the movement. And what is more, Libets experiments did not investigate the problem of free will. The free decision of a participant in Libet's experiment has been made already before the start of the experiment, namely when he gave the instruction to his subjects and they have agreed. The decision is not made again and again prior to every single finger movement!

Our frontal brain delegates such simple, stereotyped movements to phylogenetically older parts of the brain, e.g. the basal ganglia. These are incorporated into what is called the *motor loop* (cortico-basal ganglia-thalamo-cortical loop, see below). Only in the 'last minute' when everything is already prepared, the decision comes back to the cortex, in order to check whether the present moment is he right one to start the voluntary movement, and the cortex has still time enough to make changes, i.e. to adapt the intended movement to the actual needs including the actual situation in the external world. These changes need consciousness, and this is the reason why consciousness is switched on 'last minute' so to say, i.e. some 200 msec prior to the planned onset of movement. These changes can be done to the extent that the movement is not executed at all. This means that the subject can say 'no' in the last minute or as Libet puts it can place a 'veto' on the intended movement. And Libet concluded: In the *control* of the movement we are free (because we can veto an intended movement!), however, in the *initiation* of the movement we are unfree, he says (because the readiness potential starts earlier than subject´s conscious awareness). Libet says: 'Indeed, the experimental observations provide an opportunity for the occurrence of *free choice*, but apparently in the form of control rather than initiation of an act' (Libet 1990, Libet et al. 1999).

We have heard that consciousness is a very important invention of evolution, but by far not everything comes into consciousness, what enters our brain. There is as we have heard a lot of pre-filtering. These shelters imply that consciousness is not always the earliest in time. This holds for motor as for sensory systems: if we grap on a hot plate, we quickly withdraw our finger within 4-8 msec, however, only after hundreds of msec we become consciously aware that it was hot (and painful). In motor systems it does not come always early to consciousness that we want to make a movement, because the frontal brain has delegated this.

Libets scientific method is in the field of *Motor Psychophysics*, on that we worked ourselves. Imagery belongs to it, to see something in your mind's eye (Uhl et al. 1990, Goldenberg et al. 1989, vgl. auch Deecke 2005 pp. 90-97). *Introspection* is called what Libet demands from his subjects, i.e. to look into

yourself in order to find connexions that have to do with experiencing and elaboration of the experienced. The question is, however, whether one can investigate everything with the method of introspection as D. Rugg correctly commented (Behaviour & Brain Sci 1985). Libet wrote: *"The cerebral processes that precede a voluntary motor act begin some 200-350 msec before the subject is aware of his/her intention or wish to 'act-now'."*

What does it mean that in Libet´s opinion the Bereitschaftspotential is not – from the very beginning – accompanied by a conscious experience of the urge to move? In any case, one can hardly conclude from this that man has no free will but is totally determined (Libet himself and e.g. Roth 2001). Such deterministic position, which by the way also was Freud's doctrine, is not tenable. In a BP experiment, subjects make a large number of repeated movements necessary for the averaging procedure, i.e. they are working in a certain *'set.'* The original plannning and decision is, however, not investigated by this because this agenda has already been dispatched prior to the experiment via the experimenter´s instruction. Here is the instruction, Libet gave to his subjects: *"The subject is ... instructed to allow each such act to arise 'spontaneously', without deliberately planning or paying attention to the 'prospect' of acting in advance. ... For each task were subjects asked to perform a simple quick flexion of the wrist or fingers at any time they felt the 'urge' or desire to do so; timing was to be entirely 'ad lib', i.e. spontaneous and fully endogenous."* (Libet 1985, S. 530). Subjects agreed to this instruction, gave an 'informed consent' so to say.

When the experiment starts running, the subjects with the primary decision already made, perform their movements, the simple finger movements according to instruction, one after the other until they have reached the sufficient number for averaging, and the BP can be extracted from the noise of the EEG. Now we understand, that the repetition of simple stereotyped movements are not particularly suitable to investigate the question whether we have free will or not! The retrospective recall on the 'clock of seconds' is not what we normally do, it is somehow artificial and gives the experiment features of a CNV experiment, i.e. the revolving pointer on the dial may serve as an external trigger for the subject.

The conscious experience of the *'urge' to move* is according to Libet about 200 msec prior to the muscular contraction (Libet, 1990). This is roughly the same time as is necessary for the reaction to an expected (auditory) stimulus. Although the decision to make a movement has been made earlier as mentioned above, consciousness is switched on in order to make possibly necessary changes ('*last minute changes'*). These changes with the extreme to veto the movement entirely are the reason why consciousness is switched on, but not the only one. The other reason is that by this we can l e a r n from the movement. In both cases (1. *last minute changes* and 2. learning) the following brain regions are activated: The supplementary motor area (SMA, more precisely the *pre-SMA)*, the anterior portion of the cingulate gyrus, a part of the motor cortex (MI) and a region in the *basal ganglia* (Cunnington et al. 2002).

Ross Cunnington, our guest scientist from Australia, investigated in our laboratory in Vienna the question, whether the BP-Paradigm can be studied using functional magnetic resonance imaging (fMRI) in an event-related manner (we call it in the meantime 'event-related fMRI', Cunnington et al. 1999). We were successful in recording a BP equivalent in the hemodynamic Bold-response of the fMRI. This was realized with a 3 Tesla fMRI system. The term *'Bereitschafts-BOLD Response'* has been coined. BOLD means *blood oxygen level dependent* and measures the hemodynamic response in its exact time course with a temporal resolution of down to 100 msec. The Bereitschafts-BOLD-Response even resembles the Bereitschaftspotential (BP) or readiness potential in its form, it only is delayed in time. With this method, the order of activation has been investigated and is in agreement

with the order of the neural events using EEG and MEG recordings: First the supplementary motor area (SMA) as well as the cingulate motor area (CMA), and only later the primary motor area (MI) is activated, exactly as postulated by Deecke & Kornhuber, 1978; i.e. the Bereitschafts-BOLD-Response has an early and a late component just like BP1 (*early BP*) and BP2 (*late BP*), whereby the early is generated by the SMA/CMA complex, the late component by the primary motor cortex MI. It is good to know from Libet now, that the activity of SMA/CMA is unconscious as is the activity of the basal ganglia; however, activitation of the primary motor area (MI, generating BP2) becomes conscious.

Cunnington et al. 2000, 2002 made the important observation that activity in the sense of the Bereitschafts-BOLD-Response can be recorded not only in the cortex but *in the basal ganglia* as well. Rektor et al. 2001 and Rektor 2003 reported that they recorded with intracerebral recordings directly from the brain a Bereitschaftspotential in the basal ganglia. These two findings are very important and can be understood in the light of the 'motor loop' (cortex → basal ganglia → thalamus → cortex; cf. Kornhuber, 1974a; DeLong, 1990; Alexander, 1990). The activity that runs via this loop comes from the SMA/CMA and goes to the MI – on its way obviously making use of the subroutine systems of the basal ganglia. In this connexion, the '*chunking* hypothesis' is noteworthy (Gerloff et al. 1997). These interesting 'transient lesion experiments' that they are (cortical stimulation with high frequency trains of magnetic stimuli) confirm very well our SMA hypothesis, in that we see in the SMA an instructor, or supervisor or job distributor. The SMA organises sequential movements and actions in such a way that it chunks the sequences down to handy bits and determines the appropriate *time slots* for their launching, just the way a right job distributor does.

In conclusion, experiments of the Libet type cannot be considered as an argument against free will of man. They do not investigate the problem of freedom. What would be necessary to study, is the original planning and decision; this, however, has been completed already before the experiment has started. Repetitions of stereotyped simple movements are not suitable for investigation into the question whether we have free will or not.

The method of investigation that led to the discovery of the Bereitschaftspotential aimed at exploring the *intentionality of man*. We believe that a total determinism does not apply for us humans. Nor does absolute freedom. Absolute freedom is not available for us. Freedom always comes in degrees. It is important to re-introduce volition and will into the key word thesauri of psychology, the life sciences, neurosciences, psychiatry and philosophy. We have certain degrees of freedom in our decisions and actions. We are talking of reasoned will (Deecke & Kornhuber 2003; Kornhuber & Deecke 2007). We have seen that man is more than a complex of genetic and environmental influences and that our r e a s o n e d w i l l has goals beyond ourselves. In this sense will and volition although only equipped with restricted freedom, are very powerful tools that have to be refined and sublimed by every individual personality.

Conscious and unconscious processes in the brain always work together. The information processing in the brain needs space, time and energy, it rests on cooperation in a distributed system of neurons, but with a striving for unity.

References:

Alexander GE, Crutcher MD, DeLong MR (1990): Basal ganglia-thalamocortical circuits: Parallel substrates for motor, oculomotor, "prefrontal" and "limbic" functions. In: Uylings, H.B.M. et al. (eds.): The prefrontal cortex. Amsterdam, New York, Oxford: Elsevier, 119-146

Cunnington R, Windischberger C, Deecke L, Moser E (1999) The use of single event fMRI and fuzzy clustering analysis to examine haemodynamic response time courses in supplementary motor and primary motor cortical areas. *Biomed Technik* 44 (Suppl 2): 116-119

Cunnington R, Erdler M, Mayer D, Asenbaum S, Deecke L (2000). Premovement cortical activity in hemi-Parkinson´s disease: a study of whole-scalp magnetoencephalography. *Movement Disorders* 15 (Suppl 3): 82

Cunnington R, Windischberger C, Deecke L, Moser, E (2002) The preparation and execution of self-initiated and externally-triggered movement: a study of event-related fMRI. *NeuroImage* 15: 373-385.

Deecke L & Kornhuber HH (1978). An electrical sign of participation of the mesial 'supplementary' motor cortex in human voluntary finger movement. *Brain Res* 159: 473-476

Deecke L (2005) Freies Wollen und Handeln aus dem Urgrund der Seele. In: MF Peschl (Hrsg) Die Rolle der Seele in der Kognitions- und Neurowissenschaft. Auf der Suche nach dem Substrat der Seele. Würzburg Königshausen & Neumann pp 63-108

Deecke L, Kornhuber HH (2003): Human freedom, reasoned will, and the brain: the Bereitschaftspotential story. In: Jahanshahi M, Hallet M (eds): The Bereitschaftspotential. New York: Kluwer Academic/Plenum Publ., 283-320.

Delacour J (1997): Neurobiology of consciousness: an overview. Behav. Brain Res. 85, 127-141.

DeLong MR (1990) Primate models of movement disorders of basal ganglia origin *Trends Neurosci* 13:281-285

Dennett, D. (2005): Sweet Dreams. Philosophical obstacles to a science of consciousness. Cambridge Mass.: MIT Press.

Gerloff C, Corwell B, Chen R, Hallett M, Cohen LG (1997). Stimulation over the human supplementary motor area interferes with the organization of future elements in complex motor sequences. *Brain* 120: 1587-1602

Goldenberg G, Podreka I, Uhl F, Steiner M, Willmes K, Deecke L (1989). Cerebral correlates of imagining colours, faces and a map - I. SPECT of regional cerebral blood flow. *Neuropsychologia* 27: 1315-1328

Kornhuber HH & Deecke L (1964). Hirnpotentialänderungen beim Menschen vor und nach Willkürbewegungen, dargestellt mit Magnetbandspeicherung und Rückwärtsanalyse. *Pflügers Arch Eur J Physiol* 281: 52.

Kornhuber HH & Deecke L (1965). Hirnpotentialänderungen bei Willkürbewegungen und passiven Bewegungen des Menschen: Bereitschaftspotential und reafferente Potentiale. *Pflügers Arch* 284: 1-17 'Citation Classic'

Kornhuber HH (1974a). Cerebral cortex, cerebellum and basal ganglia: an introduction to their motor functions. pp 267 – 280 in Schmitt FO, Worden FG, eds, *The Neurosciences: Third Study Program.* Cambridge, Mass: MIT Press.

Kornhuber HH, Deecke L (2007) Wille und Gehirn. Edition Sirius. Aisthesis-Verlag, Bielefeld/Locarno 149 pp

Libet B, Gleason CA, Wright EW, Pearl DK (1983) Time of conscious intention to act in relation to onset of cerebral activities (readiness potential); the unconscious initiation of a freely voluntary act *Brain* 106:623-642

Libet, B. (1985). Unconscious cerebral initiative and the role of conscious will in voluntary action. *Behav & Brain Sci* 8: 529-566

Libet, B. (1990). Cerebral processes that distinguish conscious experience from unconscious mental functions. In Eccles, J.C., Creutzfeldt, O. (Eds): *The principles of design and operation of the brain.* Pontificiae Academiae Scientiarum Scripta Varia 78, pp 185-202, Rome Vatican

Libet, B., Freeman, A., Sutherland, K., eds (1999). *The volitional brain: towards a neuroscience of free will.* Imprint Academic, Thorverton, UK

Rektor I, Kubova D, Bares M (2001) Movement-related potentials in the basal ganglia: an SEEG readiness potential study. *Clin Neurophysiol* 112: 2146-2153

Rektor, I. (2003). Intracerebral recordings of Bereitschaftspotential and related potentials in cortical and subcortical structures in human subjects. In M Jahanshahi, M Hallett (Eds) *The Bereitschaftspotential, movement-related cortical potentials.* Kluwer Academic / Plenum Publishers ISBN 0-306-47407-7

Roth G (2001) *Fühlen, Denken, Handeln. Wie das Gehirn unser Verhalten steuert.* Frankfurt am Main. Suhrkamp

Rugg MD (1985) Are the origins of any mental process available for introspection? Discussion to Libet, B. (1985). Unconscious cerebral initiative and the role of conscious will in voluntary action. *Behav & Brain Sci* 8: 529-566

Singer, W. (2002): Vom Gehirn zum Bewusstsein. In: Der Beobachter im Gehirn. Frankfurt: Suhrkamp

Steinbuch, K.(1965): Automat und Mensch. 3. Aufl. Heidelberg: Springer.

Uhl F, Goldenberg G, Lang W, Lindinger G, Steiner M, Deecke L (1990) Cerebral correlates of imagining colours, faces and a map - II. Negative cortical DC-potentials. *Neuropsychologia* 28: 81-93

Wiener N (1948) Cybernetics, or control and communication in the animal and the machine. Wiley, New York