

UC Merced

Proceedings of the Annual Meeting of the Cognitive Science Society

Title

Can Modern Neuroscience Change Our Idea of the Human?

Permalink

<https://escholarship.org/uc/item/99r800z9>

Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 37(0)

Author

Kotchoubey, Boris

Publication Date

2015

Peer reviewed

Can Modern Neuroscience Change Our Idea of the Human?

Boris Kotchoubey (boris.kotchoubey@uni-tuebingen.de)

Department of Medical Psychology, University of Tübingen, Silcherstr. 5,
Tübingen, 72076 Germany

Abstract

The paper briefly reviews the contribution of recent neuroscience findings to our understanding of our human nature – more exactly, to the understanding of the three properties that we conceive of as highly-specifically human: consciousness, freedom, and language. The analysis yields rather surprising results. Self-consciousness is possibly not the highpoint of our sophisticated cognitive functions, but rather the basic pre-reflective self-other distinction intimately related to body control and affective states, within whose limits cognitive processes become possible. Freedom is not a violation of natural (biological) laws, but, in contrast, a necessary attribute of complex behavior; it roots in the fundamental biomechanical freedom of biological movements. Language comprehension is neither an instinct nor a set of complex inferences, but a behavior based on learnt hierarchy of predictive, anticipatory processes. Thus the answer to the question formulated in the title is positive: yes, it can change. From the author's viewpoint, these changes emphasize embodied, enacted nature of the specifically human functions.

Keywords: consciousness; freedom; language; neuroscience; *specificum humanum*

Our most general ideas about what it is to be a human being were traditionally shaped by humanitarians such as philosophers, anthropologists, and theologians. Only recently, natural scientists and particularly neuroscientists have raised a claim to participate in this process or even to play the leading role in it. As might be expected, this claim elicited a protest in the camp of humanities, whose representatives maintained that biological facts cannot directly contribute to such cultural entities as our idea of the human. Leaving this much too general discussion aside, I'll concentrate here on particular features that we commonly regard as specifically human: we think about ourselves as **self-conscious** beings, whose actions possess a considerable amount of **freedom**, and who uniquely use a **symbolic language** in their communication and thinking. I neither claim that these three features are the complete list of presumably specific properties of humans, nor that they are independent of each other. I merely ask whether facts of neuroscience can shed light at our basic conceptions of consciousness, freedom, and language.

Self-Consciousness

We are still very far away from the discovery of the **sufficient** biological conditions of consciousness. We are even unable to disprove a radical humanitarian critique which maintains that such sufficient conditions will never

be found. However, in the last years we learned a lot about **necessary** neurobiological conditions of consciousness, and this knowledge, albeit moderate, is not negligible. If we attempt to summarize the main findings about the neurobiological underpinnings of consciousness, they are the following:

First, consciousness is the matter of the whole brain. It is not localizable, even though the role of different brain structures can be very different. Information processed in various, spatially remote cortical and subcortical networks has to be integrated in order to reach consciousness (Tononi, 2008). Local information processing, however complex and "high-level" this information might be, does not necessarily involve consciousness (van Gaal & Lamme, 2012; Kotchoubey et al., 2013). We can put complex goals, strictly follow these goals in our behavior (e.g., Kiefer & Brendel, 2006; Kiefer & Martens, 2010), understand semantics and syntax, and distinguish truth from lie (Kotchoubey et al., 2014) – as long as all these processes remain local and highly specialized, they do not require conscious awareness.

Second, self-consciousness is closely related to the activity of midline structures of the brain that are also connected to basic processes of body control (Fernandez-Espejo et al., 2012; Herbert, Herbert & Pauli, 2011; for review, see Northoff, 2013). Brain areas activated during processing of self-related information are not those activated by highly complicated and difficult cognitive tasks, but rather, they overlap with the components of the Default Mode Network, which is maximally active in rest (Northoff et al., 2006).

Third, neurophysiological data indicate that consciousness is probably a multi-level system. There is a long tradition in Western thinking to regard consciousness as a binary ("all-or-none") phenomenon. According to this view a system can be either conscious or not, but nothing in between. Typical representatives of this position are, in classical philosophy, Descartes (1988); in the contemporary philosophy of mind, D. Chalmers (Chalmers, 1996); in psychology, B. Baars (Baars, 1988); and in neuroscience, S. Dehaene (e.g., Dehaene et al., 2006). Examples of the opposite views are, in classical philosophy, E. Husserl (Husserl, 2009); in the modern philosophy of mind, N. Block (Block, 2007); and in neuroscience, A. Damasio and J. Panksepp (Damasio, 1999; Panksepp, 2005).

We examined about sixty patients with the diagnosis vegetative state, which implies the complete lack of conscious awareness. fMRI were recorded in five experiments, three of which were purely cognitive tasks: mental imagery (Monti et al., 2010), a verbal task

(presentation of factually correct vs. incorrect sentences), and trace conditioning (short-term memory). The expected activity in the relevant brain regions (indicating that higher cognitive functions were at least partially preserved) was obtained only in < 10% patients. This number is well in accord with the data of other groups (e.g., Monti et al., 2010). Two other experiments involved affective stimuli that addressed the broadly disseminated network called “the pain matrix of the brain” (rev. Kupers & Kehlet, 2006). Different components of this matrix responded to pain stimuli in > 50% of the patients. In many patients, these reactions also included the activation of such higher-level regions as the anterior insula and the anterior cingulate cortex (Markl et al., 2013). Brain imaging data on healthy individuals and conscious patients indicate that the activation of these areas usually correlates with subjective feeling of pain (e.g., Colocca & Benedetti, 2005). Moreover, also in > 50% patients the pain matrix of the brain similarly responded to pain cries of other people, although these were not nociceptive but auditory stimuli (Yu et al., 2013). These and a number of similar findings (e.g., Celesia, 2013; Kotchoubey, Kaiser, Bostanov, Lutzenberger, & Birbaumer, 2009; Lotze, Schertel, Birbaumer, & Kotchoubey, 2010) suggest that many individuals who have completely lost all components of **cognitive** consciousness (conscious comprehension of language, intentional actions, declarative memory, voluntary attention, etc.) may nevertheless **experience** pain and pleasure and perhaps even understand affective states of other people (Panksepp et al., 2007; Kotchoubey et al., 2011). Apparently, low-level consciousness (with its very important component, affective consciousness: Panksepp, 2005) can exist when high-level consciousness is lacking.

To sum up, these data about the neurological underpinnings of consciousness are at variance with a broadly spread and well-respected idea of self-consciousness as a summit of human cognition, its top level. Rather, it is a background intimately linked with the basic aspects of human life and survival (Northoff, 2013). Looking back to the great philosophical models of the past, one may say that self-consciousness of the present-day neuroscience is much more like the phenomenological model of Husserl or the “being-there” model of Heidegger than to largely cognitive models of Descartes, Spinoza, or Kant.

Freedom

A simple naturalistic argument against freedom of human action is that any action is actually a movement (or a combination of movements), and that the neural control of movements is a deterministic chain of events within which no space for free and unpredictable events is left. An executive area of the brain (e.g., the dorsolateral prefrontal cortex), taking into account emotional, motivational, social and other influences, makes a decision; on the basis of this decision the premotor cortex formulates an action program; the primary motor cortex transforms this program into a

motor command that is sent to cranial nerve nuclei or the spinal cord; and the latter does not have other choice than to obey the command.

Of course, every determinist admits that the above scheme is very rough. The point is, however, that movement science has demonstrated that such deterministic schemes are not just rough. They are simply wrong. The brain does not (because it cannot) play on muscles like a musician plays on a keyboard (Requin, 1985; Turvey, 1990). The brain is unable to solve the so-called Bernstein’s problem (Bernstein, 1967): the number of degrees of freedom (DFs) in any movement of a complex animal (such as a bird, a dog, or a human) is by several orders larger than the number of DFs an executive system can control. Even a relatively simple action (e.g., grasping a glass of water, keeping it with five fingers and bringing it to the mouth) can be realized by many millions of nearly equivalent activation patterns at the spinal level, all of them leading to the same result (Latash, Scholz & Schöner, 2007; Latash, Gorniak & Zatziorski, 2008). If the executive calculates all advantages and disadvantages of each particular combination of neural excitations resulting in the movement described above, and finally chooses the optimal pattern, these calculations would take time largely exceeding the life time of the organism. Movements under exact control of the brain are possible and even necessary at a first step of motor learning, when an efficient movement synergy as a self-regulatory system is not yet built up (e.g., when a first-grader learns to write letters). However, such movements are highly energy consuming, and learning consists in their replacement with uncontrolled, self-organized movements (Latash et al., 2008; Vereijken, van Emmerik, Whiting, & Newell, 1992). The biomechanical freedom of movements is necessary for adaptation of a complex organism to its complex environment.

Modern kinesiology views a movement as a self-organized, self-regulating multilevel system, in which each higher level can only set a very limited number of control parameters, leaving everything else to the next lower level (Turvey, 1990; Latash, 2012). The higher level does not know, how exactly the parameters are controlled (the “principle of executive ignorance”: e.g., Turvey, 1977). Even though such systems are principally deterministic (i.e., they can be mechanistically described in retrospect), their operations cannot be predicted in advance (Latash, 2012). A carpenter may make some 10 million hammer strokes during his professional life; but hardly two of these strokes are identical. The main reason of why the brain of a scientist cannot predict the next movement of her subject is the fact that the subject’s own brain cannot. A movement is created in the course of its execution.

Another factor that has only recently attracted the attention of researchers is the stochastic nature of the essential processes in the nervous system, such as ionic membrane transfer and synaptic transmission (e.g., Linden, 2007; Finke, Braun, & Feudel, 2010; Rolls & Deco, 2010). Both processes contain noise that cannot be removed by any

technique (Braun et al., 2011). The meaning of this irreducible noise remains unclear, and one may believe that noise-produced small random fluctuations of neural excitability, averaged in space and time, do not produce any effect at the macro-level, i.e., at the level of behavior. However, the data cited above demonstrate that movement control at the peripheral level has principally chaotic character (Kelso & Ding, 1993; Latash, 2012). If this holds true also for the central control mechanisms, one can speculate that the tiny fluctuations at the micro-level might not be behaviorally neutral (Braun, Moss, Postnova & Mosekilde, 2008), because chaotic processes can serve as powerful amplifiers of minimal changes due to the so called butterfly effects.

Of course, neither the irreducible noise in neural micro-processes nor the chaotic complexity of behavioral control can present a full explanation of freedom or justify this notion as it is used in common language. Additional assumptions are necessary for this sake, which I tried to analyze in details elsewhere (Kotchoubey, 2012). The above mentioned discoveries do not “prove” the freedom of human actions, but they rebut deterministic arguments against the notion of freedom thus removing the illusory opposition between freedom and natural science.¹

Language

“All attempts to teach great apes spoken language have failed.” This opening sentence of the most recent review about the evolution of acoustic communication (Ackermann, Hage, & Ziegler, 2014, p.529) indicates that language continues to attract attention as a **specificum humanum**, as something radically separating human beings even from their closest phylogenetic relatives. The prevailing idea of language comprehension during the last decades has been like this: Visually or acoustically perceived words are processed by means of three main modules: syntax, semantics, and pragmatics. The processing in these modules is sequential and consists of processing stages. Syntax is strongly separated from both semantics and pragmatics and represents „the essence of language“: to understand language means to understand syntax (e.g., Chomsky, 1965; Pinker, 1994). Syntactic processing (and, thereby, language processing in general) is mainly genetically determined,

¹ There is no space here for an obsolete analysis of the studies claiming to find electrophysiological or metabolic predictors of human actions. Such analyses have already been performed by numerous philosophers (e.g., Dennett, 1991), psychologists (e.g., Trevena & Miller, 2010) and neuroscientists (e.g., Herrmann, Pauen, Min, Busch, & Rieger, 2008) and revealed methodological flaws of such severity (including even arithmetic errors: Trevena & Miller, 2002) that a serious discussion of these experiments in 2014 is not worthy any longer. The most what these experiments really have shown are trivialities such as (i) there are preparatory processes in the brain, and (ii) voluntary actions are not necessarily performed in full awareness (everybody who drives a car or a bike knows this).

while the factors of language usage play relatively minor roles.

The data obtained using the methods of neuroscience require, from my point of view, substantial corrections of this picture. Thus according to the sequential principle, we match the perceived words with units of our built-in lexicon and thus identify their meaning (e.g., a combination of five signs *sugar* means a white soluble substance with a characteristic taste, chemically a linkage of glucose and fructose). This meaning is then compared with other lexical units already identified before, e.g., with the context of the sentence. If the meaning of the newly perceived word agrees with the context (semantic match), the processing runs further; if it does not (“semantic mismatch”) a broad network in the brain is activated to integrate the word into the context. The best known physiological indicator of this activation is an electrically negative deflection in the EEG with a peak latency of about 400 ms after the semantically inappropriate word, called N400 (Kutas & Hillyard, 1980). After this micro-context (within a sentence or an expression) is established, the word is connected with a macro-context which includes the whole conversation, the discourse, the previous knowledge about the matter, etc.

First, the originally suggested link between EEG components and language processing modules (N400 – semantic module; late positive complex [LPC] – syntactic module) is not supported by recent data. Thus LPC can be elicited by virtually any kind of linguistic violation (Münte, Heinze, Matzke, & Wieringa, 1998; Kotchoubey & Lang, 2003). The false impression of modular specificity was partially caused by confusion between language domains and communicational ambiguity, with semantic violations being in general much more equivocal (inducing higher ambiguity) than syntactic violations (Kotchoubey, 2006).

In our experiment, we presented not only typical ambiguous semantic violations (*A waiter served tea with milk and shoes*) and unequivocal syntactic violations (*I expect that he comes*), but also unequivocal semantic violations (e.g., *A hungry man is an angry lamp*) and rather ambiguous syntactic violations (e.g., *He is playing piano with passionately*). The former were constructed so that only one correct word (*man*) could replace the incongruent word at the end of the sentence. The latter allowed for at least two different ways of syntactic repair (e.g., *He is playing piano with passion* or *He is playing piano passionately*), both of which had approximately the same meaning (otherwise the sentence would be semantically ambiguous!). The ambiguity factor indicates how much of the message can yet be understood despite the violation. It should be emphasized that ambiguous syntactic violations were still much less ambiguous than ambiguous semantic violations, i.e., the match of the ambiguity level was not perfect. However, the main results presented in Figure 1 show that notwithstanding this limitation the ambiguity factor was at least as important as the language domain. This finding does not, of course, disprove the general theory of processing modules, but indicates that the different

behavior of different EEG components is better explained but factors other than modular specificity.

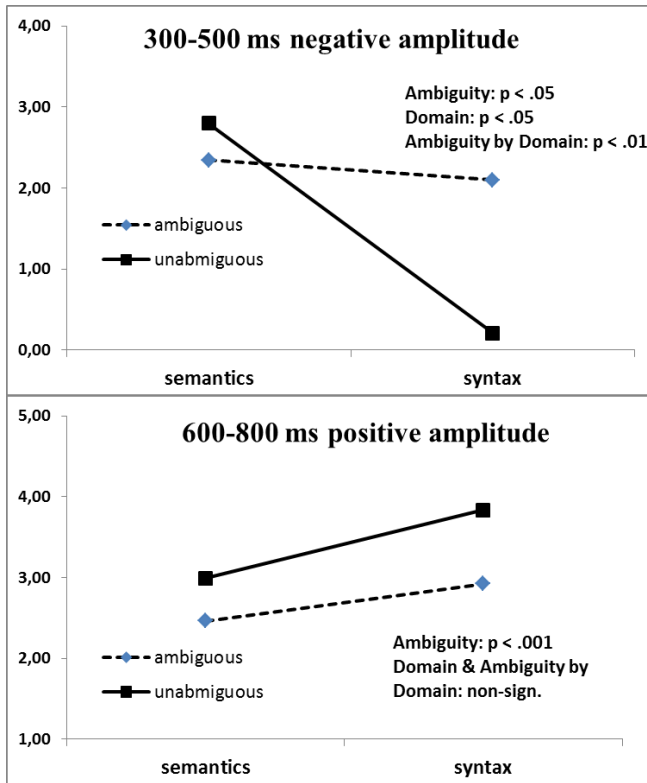


Figure 1: The amplitudes (in μV) of two typically recorded EEG components (N400 and LPC) as a function of language domain (semantics vs. syntax) and ambiguity. Top panel: N400 amplitude. Bottom panel: LPC amplitude. Both components were measured at the Pz lead as mean amplitudes in the time windows of 250-500 ms and 500-800 ms, for N400 and LPC, respectively.

As said above, a sentence like *A waiter served tea with milk and shoes* is highly typical for elicitation of the N400, because its end word is semantically incongruent. However, the sentence *There were nuclear weapons in Iraq* is semantically congruent, but also elicits an N400, at least in those who know that there were none (Hagoort, Hald, Bastiaansen, & Petersson, 2004). Fully congruent are sentences *My favorite music is Chopin* and *Perhaps I am pregnant*, but the former also elicits the N400 if presented together with a picture of a punk, and the latter, if spoken with a male voice (Van Berkum, Brown, Hagoort, & Zwitserlood, 2003). Finally, the harmless *The nut was salted* elicits a strong N400 after we have heard a fairy tale in which the nut was a young man, and *The nut fell in love* does not elicit an N400 after this tale. Notably, the properties of the N400 in all these completely different situations (its waveform, latency, scalp distribution) are virtually the same (Hagoort & Van Berkum, 2007).

The language processing system does not wait for verbal information but actively extracts this information from the

incoming stimuli. In the sentence *Eva seduced Adam to eat a...* the N400 is elicited already to the article *a* (expected *an*), although *a* is a function word devoid of the own content, thus it cannot be semantically integrated (DeLong, Urbach, & Kutas, 2005). Our recent analysis has demonstrated that ambiguous words immediately and strongly activate their context-appropriate meaning, even if a different meaning dominates in an individual's lexicon; e.g. the meaning of *queen* as a female monarch strongly dominates over its meaning as a chess piece, but the dominant meaning is suppressed in a sentence like *The chess master moved his queen* (Kotchoubey & El-Khoury, 2014).

In sum, these data are compatible with a model of language different from that which we began this section with. Language is not an instinct, but a behavior which, despite all its peculiar properties, is ruled by the same basic mechanisms of behavioral control as any other behavior. This behavior is aimed at pragmatic objectives, i.e., to communicate, to understand other individuals and to be understood by them. The syntax is a very particular mean used for communication, but only a mean and not „the essence“ of language; understanding language means not understanding syntax, but rather understanding its use for communication.

Importantly, language is a very demonstrative example of a general principle of predictive activity of the brain (e.g., Clark, 2013; for a formal approach to this principle, see Friston, Daunizeau, Kilner, & Kiebel, 2010). Language comprehension is not a passive processing of verbal stimuli but a continuous hypotheses-making and hypotheses-testing project, based on a complex and flexible hierarchy of anticipations (Kotchoubey, 2006). This is a model that is always ahead of the arriving messages, which are used to confirm, correct or upgrade it.

Conclusion

Our brief review of the contribution of neuroscience to our idea on three principal human features (i.e., self-consciousness, freedom, and symbolic language) results in fairly unexpected conclusions. Our self-consciousness is possibly not the top of our most sophisticated cognitive functions, but rather the basic pre-reflective self-other distinction intimately related to body control and affective states, within whose limits cognition processes become possible (e.g., Northoff, 2013). Freedom is not a violation of natural (biological) laws, but, in contrast, a necessary attribute of complex behavior; it roots in the fundamental biomechanical freedom of a biological movement. The data of neuroscience do not exhaustively explain freedom (like they do not exhaustively explain consciousness), but they make it a natural phenomenon that can be investigated with methods of neurobiology (e.g., Kotchoubey, 2012). Language comprehension is neither an instinct (a simple nature's gift), nor a set of complex cognitive inferences, but a behavior based on learnt hierarchy of predictive, anticipatory processes (e.g., Tomasello, 2003). The answer

to the question formulated in the title is, therefore, positive: yes, data of neuroscience can modify our idea of ourselves. However, the direction of the change is at variance with that straightforward mechanistic and computer-like kind of explanation that is publicly expected. Rather, these changes emphasize embodied, enacted nature of the specifically human functions.

Acknowledgment

I am very grateful to N. Birbaumer, S. Lang, A. Markl, F. Müller and T. Yu for their contribution in patient studies whose data are used in the present paper.

References

- Ackermann, H., Hage, S. R., & Ziegler, W. (2014). Brain mechanisms of acoustic communication in humans and nonhuman primates: An evolutionary perspective. *Behavioral & Brain Sciences*, *37*, 529-604.
- Baars, B. J. (1988). *A Cognitive Theory of Consciousness*. Cambridge, UK: Cambridge University Press.
- Bernstein, N. A. (1967). *The Coordination and Regulation of Movements*. Oxford: Pergamon.
- Block, N. (2007). Consciousness, accessibility, and the mesh between psychology and neuroscience. *Behavioral & Brain Sciences*, *30*, 481-499.
- Braun, H. A., Moss, F., Postnova, S., & Mosekilde, E. (2008). Complexity in neurology and psychiatry. *Journal of Biological Physics*, *34*, 249-252.
- Braun, H. A., Schwabedal, J., Dewald, M., Finke, C., Postnova, S., Huber, M. T., Wollweber, B., Schneider, H., Hirsch, M. C., Voigt, K., Feudel, U., & Moss, F. (2011). Noise-induced precursors of tonic-to-bursting transitions in hypothalamic neurons and in a conductance-based model. *Chaos*, *21*, Article 047509.
- Celesia, G. (2013). Conscious awareness in patients in vegetative states: Myth or reality? *Current Neurology Neuroscience Reports*, *13*, Article 395.
- Chalmers, D. J. (1996). *The Conscious Mind: In Search of a Fundamental Theory*. New York: Oxford University Press.
- Chomsky, N. (1965). *Aspects of the Theory of Syntax*. Harvard, MA: MIT Press.
- Clark, A. (2013). Whatever next? Predictive brains, situated agents, and the future of cognitive science. *Behavioral & Brain Sciences*, *36*, 181-204.
- Colocca, L., & Benedetti, F. (2005). Placebos and painkillers: Is mind as real as matter? *Nature Review Neuroscience*, *6*, 545-552.
- Damasio, A. R. (1999). *The Feeling of What Happens: Body and Emotion in the Making of Consciousness*. San Diego: Harcourt.
- Dehaene, S., Changeaux, J. P., Naccache, L., Sackur, J., & Sergent, C. (2006). Conscious, preconscious, and subliminal processing: A testable taxonomy. *Trends in Cognitive Sciences*, *10*(5), 204-211.
- DeLong, K. A., Urbach, T. P., & Kutas, M. (2005). Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. *Nature Neuroscience*, *8*, 1117-1121.
- Dennett, D. (1991). *Consciousness Explained*. Boston-Toronto-London: Little, Brown and Co.
- Descartes, R. (1988). *Selected Philosophical Writings*. Cambridge, UK: Cambridge University Press.
- Fernandez-Espejo, D., Soddu, A., Cruse, D., Palacios, E. M., Junque, C., Vanhauzenhuysse, A., Rivas, E., Newcombe, V., Menon, D. K., Pickard, J. D., Laureys, S., & Owen, A. M. (2012). A role for the default mode network in the bases of disorders of consciousness. *Annals of Neurology*, *72*, 335-343.
- Finke, C., Braun, H. A., & Feudel, U. (2010). The role of intrinsic dynamics and noise for neural encoding and synchronization. *BMC Neuroscience*, *12*, 1-2.
- Friston, K. J., Daunizeau, J., Kilner, J., & Kiebel, S. J. (2010). Action and behavior: A free-energy formulation. *Biological Cybernetics*, *102*, 227-260.
- Hagoort, P., Hald, L., Bastiaansen, M., & Petersson, K. M. (2004). Integration of word meaning and world knowledge in language comprehension. *Science*, *304*, 438-441.
- Hagoort, P., & Van Berkum, J. J. A. (2007). Beyond the sentence given. *Philosophical Transactions of the Royal Society London, Series B*, *362*, 801-811.
- Herbert, C., Herbert, B., & Pauli, P. (2011). Emotional self-reference: Brain structures involved in the processing of words describing one's own emotions. *Neuropsychologia*, *49*, 2947-2956.
- Herrmann, C. S., Pauen, M., Min, B. K., Busch, N., & Rieger, J. W. (2008). Analysis of a choice-reaction task yields a new interpretation of Libet's experiments. *International Journal of Psychophysiology*, *67*, 151-157.
- Husserl, E. (2009). *Philosophie als strenge Wissenschaft*. Hamburg: Felix Meiner Verlag.
- Kelso, J.A.S., & Ding, M. (1993). Fluctuations, intermittency, and controllable chaos in biological coordination. In K. Newell & D. Corcos (Eds.), *Variability and Motor Control* (pp. 291-316). Champaign, IL: Human Kinetics Publishers.
- Kiefer, M., & Brendel, D. (2006). Attentional modulation of unconscious "automatic" processes. *Journal of Cognitive Neuroscience*, *18*(2), 184-198.
- Kiefer, M., & Martens, U. (2010). Attentional sensitization of unconscious cognition: Task sets modulate subsequent masked semantic priming. *Journal of Experimental Psychology: General*, *139*(3), 464-489.
- Kotchoubey, B. (2006). Event-related potentials, cognition, and behavior: A biological approach. *Neuroscience & Biobehavioral Reviews*, *30*, 42-65.
- Kotchoubey, B. (2012). *Why Are You Free?* Hauppauge, N.Y.: Nova Science Publishers.
- Kotchoubey, B., & Lang, S. (2003). Parallel processing of physical and lexical auditory information in humans. *Neuroscience Research*, *45*, 369-374.

- Kotchoubey, B., Kaiser, J., Bostanov, V., Lutzenberger, W., & Birbaumer, N. (2009). Recognition of affective prosody in brain-damaged patients and healthy controls: A neurophysiological study using EEG and whole-head MEG. *Cognitive, Affective & Behavioral Neuroscience*, 9, 153-167.
- Kotchoubey, B., Yu, T., Markl, A., Vogel, D., Müller, F., & Lang, S. (2011). On the way to the deep layers of consciousness. *Advances in Clinical Neuroscience and Rehabilitation*, 11, 10-13.
- Kotchoubey, B., Merz, S., Lang, S., Markl, A., Müller, F., Yu, T., & Schwarzbauer, C. (2013). Global functional connectivity reveals highly significant differences between the vegetative and the minimally conscious state. *Journal of Neurology*, 4, 975-983.
- Kotchoubey, B., & El-Khoury, S. (2014). Event-related potentials indicate context effect in reading ambiguous words. *Brain & Cognition*, 92, 48-60.
- Kotchoubey, B., Yu, T., Mueller, F., Vogel, D., Veser, S., & Lang, S. (2014). True or false? Activations of language-related areas in patients with disorders of consciousness. *Current Pharmaceutical Design*, 20, 4239-4249.
- Kupers, R., & Kehlet, H. (2006). Brain imaging of clinical pain states: A critical review and strategies for future studies. *Lancet Neurology*, 5, 1033-1044.
- Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science*, 207, 203-205.
- Latash, M. L. (2012). *Fundamentals of Motor Control*. Amsterdam etc.: Academic Press/Elsevier.
- Latash, M. L., Scholz, J. P., & Schöner, G. (2007). Toward a theory of motor synergies. *Motor Control*, 11, 276-308.
- Latash, M. L., Gorniak, S., & Zatziorski, V. M. (2008). Hierarchies of synergies in human movements. *Kinesiology*, 1, 29-38.
- Linden, D. J. (2007). *The Accidental Mind*. Cambridge, MA: Belknap Press/Harvard University Press.
- Lotze, M., Schertel, K., Birbaumer, N., & Kotchoubey, B. (2010). A long-term intensive behavioral treatment study in patients with persistent vegetative state or minimally conscious state. *Journal of Rehabilitation Medicine*, 43(3), 230-236.
- Markl, A., Yu, T., Vogel, D., Müller, F., Kotchoubey, B., & Lang, S. (2013). Brain processing of pain in patients with unresponsive wakefulness syndrome. *Brain & Behavior*, 2, doi: 10.1002/brb1003.1110.
- Monti, M. M., Vanhauzenhuyse, A., Coleman, M. R., Boly, M., Pickard, J. D., Tshibanda, L., Owen, A., & Laureys, S. (2010). Willful modulation of brain activity in disorders of consciousness. *New England Journal of Medicine*, 362, 579-589.
- Münste, T. F., Heinze, H. J., Matzke, M., & Wieringa, B. M. (1998). Brain potentials and syntactic violations revisited: No evidence for specificity of the syntactic positive shift. *Neuropsychologia*, 36, 217-226.
- Northoff, G. (2013). *Unlocking the Brain*. Volume 2: Consciousness. New York: Oxford University Press.
- Northoff, G., Heinzel, A., de Greck, M., Bermpohl, F., Dobrowolny, H., & Panksepp, J. (2006). Self-referential processing in our brain - A meta-analysis of imaging studies on the self. *Neuroimage*, 31, 440-457.
- Panksepp, J. (2005). Affective consciousness: Core emotional feelings in animals and humans. *Consciousness & Cognition*, 14, 30-80.
- Panksepp, J., Fuchs, T., Garcia, V. A., & Lesiak, A. (2007). Does any aspect of mind survive brain damage that typically leads to a persistent vegetative state? Ethical considerations. *Philosophy, Ethics, and Humanities in Medicine*, 2 (32).
- Pinker, S. (1994). *The Language Instinct*. London: Penguin Books.
- Rolls, E. T., & Deco, G. (2010). *The Noisy Brain: Stochastic Dynamics as a Principle of Brain Function*. Oxford: Oxford University Press.
- Requin, J. (1985). Looking forward to moving soon. In M. Posner & O. Marin (Eds.), *Attention and Performance* (Vol. XI). Hillsdale, NJ: Lawrence Erlbaum.
- Tomasello, M. (2003). *Constructing a Language*. Cambridge MA: Harvard University Press.
- Tononi, G. (2008). Consciousness as integrated information: a provisional manifesto. *Biological Bulletin*, 215, 216-242.
- Trevena, J. A., & Miller, J. (2002). Cortical movement preparation before and after a conscious decision to move. *Consciousness & Cognition*, 11, 162-190.
- Trevena, J. A., & Miller, J. (2010). Brain preparation before a voluntary action: Evidence against unconscious movement initiation. *Consciousness & Cognition*, 19, 447-456.
- Turenout, M., Hagoort, P., & Brown, C. M. (1998). Brain activity during speaking: From syntax to phonology in 40 ms. *Science*, 280(5363), 572-574.
- Turvey, M. T. (1977). Preliminaries to a theory of action with reference to a vision. In R. Shaw & J. Bransford (Eds.), *Perceiving, Acting, and Knowing*. Hillsdale, NJ: Lawrence Erlbaum.
- Turvey, M. T. (1990). Coordination. *American Psychologist*, 45, 938-953.
- Van Berkum, J. J. A., Brown, C., Hagoort, P., & Zwitserlood, P. (2003). Event-related brain potentials reflect discourse-referential ambiguity in spoken language comprehension. *Psychophysiology*, 40, 235-248.
- van Gaal, S., & Lamme, V. A. F. (2012). Unconscious high-level information processing: Implication for neurobiological theories of consciousness. *The Neuroscientist*, 18(3), 287-301.
- Vereijken, B., van Emmerik, R. E. A., Whiting, H. T. A., & Newell, K. M. (1992). Free(z)ing degrees of freedom in skill acquisition. *Journal of Motor Behavior*, 24, 133-142.
- Yu, T., Lang, S., Vogel, D., Markl, A., Müller, F., & Kotchoubey, B. (2013). Patients with unresponsive wakefulness syndrome respond to the pain cries of other people. *Neurology*, 80, 345-352.