Spring February, 2011

Rethinking thecognitiverevolutionfromaneuralperspective:How

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Neuroscience and Biobehavioral Reviews 35 (2011) 2026–2035

Contents lists available at ScienceDirect

Neuroscience and Biobehavioral Reviews

journal homepage: www.elsevier.com/locate/neubiorev

Review

Rethinking the cognitive revolution from a neural perspective: How overuse/misuse of the term 'cognition' and the neglect of affective controls in behavioral neuroscience could be delaying progress in understanding the BrainMind

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ARTICLE INFO

Article history:
Received 19 August 2010
Received in revised form 13 February 2011
Accepted 14 February 2011

Keywords:
Cognition
Emotion
Motivation
Perception
Concepts
Neural activity
Behavior

ABSTRACT

Words such as cognition, motivation and emotion powerfully guide theory development and the overall aims and goals of behavioral neuroscience research. Once such concepts are accepted generally as natural aspects of the brain, their influence can be pervasive and long lasting. Importantly, the choice of conceptual terms used to describe and study mental/neural functions can also constrain research by forcing the results into seemingly useful 'conceptual' categories that have no discrete reality in the brain. Since the popularly named 'cognitive revolution' in psychological science came to fruition in the early 1970s, the term *cognitive* or *cognition* has been perhaps the most widely used conceptual term in behavioral neuroscience. These terms, similar to other conceptual terms, have potential value if utilized appropriately. We argue that recently the term cognition has been both overused and misused. This has led to problems in developing a usable shared definition for the term and to promotion of possible misdirections in research within behavioral neuroscience. In addition, we argue that cognitive-guided research influenced primarily by top-down (cortical toward subcortical) perspectives without concurrent non-cognitive modes of bottom-up developmental thinking, could hinder progress in the search for new treatments and medications for psychiatric illnesses and neurobehavioral disorders. Overall, linkages of animal research insights to human psychology may be better served by bottom-up (subcortical to cortical) affective and motivational 'state-control' perspectives, simply because the lower networks of the brain are foundational for the construction of higher 'information-processing' aspects of mind. Moving forward, rapidly expanding new techniques and creative methods in neuroscience along with more accurate brain concepts, may help guide the development of new therapeutics and hopefully more accurate ways to describe and explain brain-behavior relationships.

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doi:10.1016/j.neubiorev.2011.02.008

This essay seeks to unpack some of the potentially invidious consequences of overutilization of "cognitive" concepts in a cross-species behavioral neuroscience that is currently an increasingly robust approach to understanding the neural mechanisms that control animal behaviors. Cognition can be defined as processing of information entering the brain from the outside world through sensory portals. Although this definition and its various other usages do not typically include the most robust underlying 'CTM' vision of modern cognitivism – the pervasive Computational Theory of Mind in cognitive science – 'cognition' is widely used as a moniker for practically all the interesting functions the brain performs to facilitate behavioral adaptations and survival. We believe this wide usage leads to conceptual confusions, arising from the conflating of diverse types of brain functions under a universal label that fails to recognize critically important distinctions, especially when examining the biopsychology of attention, emotions and motivations.

We will not specifically focus on the CTM, but would simply highlight that there are increasing reasons for concern about the degree to which the brain should be envisioned primarily as a "computational device" (Panksepp, 2009). Clearly, the brain has global attentional, emotional and motivational "state functions" – widely ramifying neuropsychological processes that are not easily captured in either strict computational or cognitive terms.

1. Using cognition to describe and explain

A graduate student has to defend his dissertation research to the faculty and, at times, to the general public. If the work is on brain activity related to learning and memory using rodent models, students may be tempted to state, "Lesions to the brain impaired this cognitive process." An audience member inquires what the student means by the term cognitive. The student replies "Those mechanisms involved in learning and memory." The audience member is still puzzled and wants to know, "Are there mechanisms that do not involve learning and memory?" The student replies, "Well as far as I know everything involves learning and memory at some point." The student feels justified and actually empowered because his research has such broad implications (i.e., an inclusive "Theory of Everything"). In addition, non-critical audience members may be content with such simplified analyzes, and be at peace with logical inference that everything (at least related to this seminar) is cognitive. Of course, if they used food or shock to serve as the reward and punishment in such learning studies, the student might be hard-pressed to defend that the BrainMind features of those unconditioned mechanisms should fall solely under the "cognitive" banner. And the few spectators from the humanities may wonder why emotional feelings are never discussed, but the rest implicitly understand that such subjective terms were tossed out from rigorous behavioral research a long time ago.

A second example: a group of faculty gathers at an intimate international conference to discuss novel ways to produce and utilize animal models of mental illness. The behavioral paradigms are discussed as ways to reveal cognitive deficits seen in human "mental disease" states. The animal's behavioral impairments include alterations in choice behavior, object recognition and in the ability to utilize time appropriately to manipulate the environment. The discussion begins to approach the topic for 'how these deficits resemble cognitive changes in human mental illness', and the panel decides that terms such as working memory and attention need to be refined and possibly standardized in order to make the 'translational' leap to human work. Another scientist inquires about stepping back one more notch in the conceptual chain and asking about 'standardizing the concept of cognitive processes'. Perhaps a courageous soul may raise the issue whether we should or should not consider emotional-experiential concepts in our discussions. No substantive attempt to reply to these issues is made, but the mini-conference moves forward in search of animal models with predictive validity in measuring cognition in human emotional disorders. "Face" and "construct validity" fall by the wayside. We have seen such passages at meetings we have attended, with relatively little focus on the detailed neural nature of the unconditioned stimuli and unconditioned responses that are routinely used to study practically all aspects of learning, memory and attention. Should we also place these critical unconditioned processes, so essential for all learning tasks, within the subset of cognitive phenomena? Or are the 'rewards' and 'punishments' that are used to push learned behaviors this way and that non-cognitive since they are depending on what appear to be internal affective functions of animal experience, rather than externally arriving information to be processed into learning by the brain. Somewhere, someone surely ponders whether the learning "glue" that is commonly called "reinforcement" is just a word for the how endogenously organized brain affective processes regulate learning processes?

These two examples demonstrate situations in which scientists have used the terms cognition and cognitive to describe what the brain is doing and to develop a model to guide biomedical research development commonly related to psychiatric disorders. The examples illustrate the fact that in some cases when the term cognition is used, it is used to describe a large and diverse set of psychological processes and in the second example, the term may be used by different people, each usage meaning something substantially different. This is just a symptom of a larger problem in psychology. As Kurt Danziger (1997) noted a while ago in his *Naming the Mind*, too much of the basic vocabulary in psychology – terms such as attitudes, emotions, intelligence, motivation, perception and personality, to name a few – do not represent "real" entities in the world ('natural-kinds') to use another problematic concept (see Zachar, 2006; and commentary by Panksepp, 2008). They represent conceptual categories, with special meanings that were invented as matters of communicative convenience, especially during the early history of psychological science. Such categories can easily become obstacles to progress, and it seems to us that the term "cognition" is growing into a whale of a problem in behavioral neuroscience.

Despite the fact that there are serious problems of overuse and misuse with each and every complex concept – from attention to temperament, so to speak – the many socially constructed categories used in psychological research tend to bleed willy-nilly into behavioral neuroscience. This review chooses to 'pick on' cognition for several reasons. These include the fact that cognition is probably the most popular overall conceptual term in diverse present day research environments of cognitive and social neurosciences, but also increasing in behavioral neuroscience. Students become part of a cognitive research group, join a cognitive neuroscience center and learn about social cognition and cognitive regulation of emotion. Throughout behavioral neuroscience research careers, individuals can develop a deep-seated yet nonproductive reliance upon a conceptual term such as cognition, while most of the primary-process 'emotional' and 'motivational' manipulations used to promote 'cognitions' have no disciplined way to be linked to such a concept.

One key point of the current review is that we believe the increasing dependence on the term cognition, along with its common overuse and misuse, especially in the field of behavioral neuroscience often skews discussions in unproductive ways. This is especially the case when considering the primary-process (evolved) aspects of the neural apparatus and functions that have typically been subsumed by classical concepts such as primal drives, emotions and motivations. Another important reason to focus on cognition is that the typical properties of cognitive models do not readily incorporate recently supported integrative functions that include dynamic neural networking that constructs organismic coherence and brain–body communication. Finally, we think

that the mapping of 'cognitive disabilities' in psychiatric disorders often misplaces the focus of what is actually leading to the behavioral impairments in these illnesses. For instance, in depression research, it might be the case that the most important question is "Why does depression feel so bad?" (see the contribution by Zellner et al., in this issue). In human addiction research, it is being realized that a key issue to consider is how various drugs influence the affective feelings of human beings (Kassel, 2010), Thus, in preclinical addiction research, should not a key question also be (see Panksepp, 2010a): What are those "good" feelings that initially promote compulsive drug consumption? And what kind of bad feelings are alleviated by various drugs when individuals are already addicted? When we begin to think in these terms, we must begin to wonder whether there might not be more appropriate nomenclatures than some kind of a global 'Brain Reward System' which remains *au courant* even though abundant alternatives have been suggested (Berridge, 2004; Panksepp and Moskal, 2008). Should the great variety of affective state changes, that certainly occur in humans, probably also in many animals, be conceptualized as a cognitive problem? We think not, even though aspects of learning and memory formation may deserve this umbrella term.

This review briefly summarizes the historical and current definitions of "cognitive" and then provides an overview for specific ways that applying cognition by these defining principles may harm research progress. Finally, we complete the review by providing possible ways to overcome the misuse of psychological terms in animal models that may be impeding the search for etiological roots of mental illness. Animal brains contain a variety of affective functions, and we need specialized terms for the ones that are reasonably well established, for instance perhaps capitalizations for the primary-process emotional networks – e.g., SEEKING, RAGE, FEAR, LUST, CARE, PANIC/GRIEF, PLAY – concentrated in subcortical somato-visceral networks of the brain (Panksepp, 1998, 2005, 2010b; Panksepp and Biven, 2011). Perhaps we should employ similar nomenclature conventions to discuss homeostatic imbalance (drive) states as well as a host of sensory rewards and punishments routinely used to promote learning.

Cognition originated from the Latin terms '*cogitos*' and '*cognoscere*' both being verbs meaning 'to think' or 'to know'. 'Descartes' famous '*Cogitos ergo sum*' meaning 'I think therefore I am' is prescient in many ways for the heavy importance we place on knowledge acquisition in behavioral neuroscience. In contrast "I feel therefore I am" never caught on in human research, when the conversation of the nature of mind was re-energized forty some years ago after enthusiasm for behavior-only analyzes diminished. The 'Cognitive Revolution' sprouted in the 1950s and 60s, and in the decade of the 70s, displaced radical behaviorism, by beginning to focus on themes of information-processing and underlying BrainMind computations (Gardner, 1985; Neisser, 1967). It was especially influential in transforming psychology, linguistics, anthropology, philosophy, not to mention artificial intelligence/computer science. Using cognition as a core set of processes that defined intervening variables involved in mental states also became a vital part of the growth of *behavioral neuroscience*, especially in learning-theory, with many of the perspectives of an earlier *physiological psychology* (e.g., Grossman, 1969) seemingly discarded. A focus on 'cognition' presumably enabled a better appreciation for brain functions engendering psychological states and learned behavioral productions. Other terms did not seem to foster this psychological to neuroscience linkage as well as "cognition" – functional terms such as emotions and motivations – presumably because of their reduced emphasis on information processing (learning and memory) and their seemingly more diffuse phenomenological relationships to central nervous system activities (Richter, 1947). However, this left critical issues – namely how the foundations of the BrainMind were constructed early in brain evolution – little discussed in the behavioral neurosciences.

Prior to the formal advent of the Cognitive Revolution in the 1970s (Gardner, 1985), cognition was used mainly to denote a sensory process that transformed input via perception to the generation of higher-order concepts (Heidbreder, 1945) or arrange belief-value systems (Tolman, 1952). The utilization of sensory inputs in the service of learned behavior patterns, in order to engender adaptive behavioral strategies, was at the heart of many definitions of cognition. However, the new, over-reaching TOE concept has engendered a back-lash from certain leaders (e.g., Fodor, 1998) who have more recently focused on how traditional human-centered cognitive science went wrong because of the ways concepts are studied and inferred from other mental representations. Still, Fodor hung on to the traditional computational information-processing vision of psychology (e.g., focusing on functionally encapsulated processes such as vision and language), while not explicitly acknowledging how ineffective that strategy might be for elucidating more global, and more endogenous, informationally open-ended, BrainMind "state-control" processes such as emotions.

The term cognition also becomes difficult to tease apart from the term perception, not to mention, as we will discuss, concepts such as emotions and motivation. If cognition subsumes all of this psychological territory, it may have lost touch with meaningful distinctions that need to be made. Neisser (1967, p. 6) provided this view clearly "Whatever we know about reality has been mediated not only by the organs of sense but by complex systems which interpret and reinterpret sensory information . . . The term 'cognition' refers to all the processes by which sensory input is transformed, reduced, elaborated, stored, recovered and used." At the heart of how behavioral neuroscience has adopted the term is the idea of computation and information processing, with a heavy reliance on the important mental processes of life time learning and memory, while neglecting the "evolutionary memories" – the "instincts" that are built into our brain by our genetic heritage.

The cognitive neuroscience approach as detailed by Kosslyn and Andersen (1992) is a three-pronged approach that includes neuroscience, experimental psychology and computer science. The textbook has five main sections that include (1) vision, (2) auditory and somatosensory systems, (3) attention, (4) memory, and (5) higher cortical functions. The last section includes language and reasoning. A more recent textbook, typical of one used by behavioral neuroscience instructors does not define cognition but defines cognitive neuroscience as "investigations of all mental functions that are linked to neural processes, ranging from investigations in animals to humans and from experiments performed in the laboratory to computer simulations" (Banich and Compton, 2011, p. 2). Another new textbook by Baars and Gage (2010) emphasizes the link between cognition and consciousness with cognitive neuroscience including all the studies of the biology of the mind. Having cognition be the sole purveyor of consciousness has been hotly debated because computations can easily be shown to be completed without an intentional or conscious process (Searle, 1992) and other psychological processes (e.g., affect) have been proposed to have their own level of consciousness, one that can be separable from the cognitive conscious process or even be dominant over the cognitive outputs (Panksepp, 1998; Damasio, 1994).

These definitions and descriptions of 'cognition' highlight some of the problems pervasive in the ways we think about complex concepts. One major problem is the fact that many investigators rely on one major concept like cognition to include everything. For instance: "Cognitive activity which refers mainly to diverse forms of thought, whether conscious or unconscious, enters virtually everything we do; we use it to pilot our lives and to be responsive to feedback from the environment that could be relevant for survival"

(Richard Lazarus in *Emotion & Adaptation* p. 6). If cognition is provided this ubiquitous property, then it is a valid question to ask what is the use of other psychological terms and what is the essential nature of a process that allows brains to be cognitive.

An alternative, data based view is that there exist a series of ancient 'state-control' processes that deserve a more explicit conceptual focus and research strategies that are in short supply in cognitive science. For instance, internal affective processes surely deserve to be brought to the forefront of thinking when we consider the nature of decision making and ruminative thoughts. In other words, the concept of 'cognition'. even when used with restraint, often remains untethered to the evolved 'animal nature' of our mind. As noted by an anonymous reviewer of this paper "the promiscuous use of that word is a mere symptom of the fact that so many theorists are seduced by the computational model" which cannot be the whole story. Clearly, we also consider the deep evolutionary understanding emerging form affective neuroscience, which demands that we rethink our central theoretical categories, and recognize that various bottom-up evolutionary controls impose enormous constraints and pressures on higher cognitive processes. Although another reviewer of this paper noted that we could also argue that the "bottom-up and top-down dichotomy may be more related to us as observers and our limited capacities than to the brain itself." This reviewer continued that such a "dichotomy may be simply irrelevant" for brain functioning ". . .being of methodological rather than neural origin." We disagree, since the brain is clearly an evolutionarily "layered" organ, where the more ancient functions are more medial and caudal in the neuroaxis, but certainly interpenetrant with the more recently evolved functions, which are generally more lateral and rostral. Such brain organization suggests both robust bottom-up and top-down nested hierarchies of neural regulations and controls (for further elaboration of this point see Northoff et al., in this issue).

We would suggest that what is desperately needed are disciplined ways to distinguish cognitive from the many unconditional MindBrain processes, from attention to diverse varieties of affective emotional systems and motivational processes that are essential for making sense of what organisms do. One possible way to parse the cognitive and many other brain processes is in the way they are linked to incoming information from the external world ('channel functions' as Marcel Mesulam (2000) called them), and the many ways evolution prepared the brain and body to respond to the exigencies of survival (the brain–body 'state functions' as distinguished by Mesulam). For Mesulam 'channel' functions are strongly linked to incoming sensory portals while 'state' functions reflect the psychologically meaningful within-brain functions (e.g., attention, emotions, and motivations), that have more robust genetic controls over their psychological functions than the external information-linked channel functions of the brain (e.g., specific perceptions, thoughts, or strategies). One way to parse this fundamental bottom-up distinction is in terms of the many conceptual distinctions that can be made between the affective and cognitive aspects of BrainMind functioning (see Table 1; Ciompi and Panksepp, 2004; Panksepp, 2003), with most primary-process affects (see Panksepp's lead essay in this issue) having a much deeper neuroevolutionary history than most cognitions.

Of course, our basic unconditioned affective and attentional processes and our cognitive interpretations of events of the world are massively blended (Lane and Nadel, 2000; Pessoa, 2008), and in brain evolution, the complexities of the cognitive apparatus appear to have been built upon, and remain interpenetrant with the many hierarchically embedded emotional and motivational state functions that are initially unconditioned tools for living but can rapidly become parts of classical- and operant-conditioning extensions of the basic unconditional organismic abilities. These distinct aspects of the brain differ in various characteristics that highlight how insufficient the guiding metaphor of cognitive science may be for understanding the brain. It is more than *just* an information-processing device. The above distinctions are not well represented in cognitive science, and we suspect that it is for this reason that some of the esteemed fathers of computational cognitivism are sharing their concerns that there is something profoundly missing from their information-only models of mind. In short, as Jerry Fodor (2000) put it: *The Mind Does Not Work That Way*, even though, as already noted, Fodor did not back-down at all on the utility of information-processing models of mind. We have no quarrel with information-processing as being key to higher cognitive functions, but we do not see it as a good descriptor of the evolutionarily intrinsic primary-process affective functions. Attention, affects and bodily drives, as well as hedonic responses to certain sensory inputs, are largely inherited brain processes (Berridge, 2000; Panksepp, 1998). As an example of the weakness of 'pure cognitivism' we will briefly develop the more affective and motivational view of mind that is essential for cognitivism to have a firmer evolutionary 'center of gravity' around which animals abundant information-processing revolves. However there are deep historical resistances within cognitive psychology for a fuller integration with our animalian past.

Table 1
Some conceptual distinctions that can be made between the affective and cognitive aspects of BrainMind functioning. These distinctions enable a separation between these psychological processes. The distinct properties include neural and functional processes that can guide how behavioral neuroscience research is completed and used by others to develop new directions in the field.

Affective processes (values) vs.	Cognitive processes (information)
More subcortical	More neocortical
Less computational (analog)	More computational (digital)
Intentions-in-action	Intentions-to-act
Action to perception controls	Perception to action controls
Neuromodulator codes	Neurotransmitter codes
(e.g., more neuropeptidergic)	(e.g., more glutamatergic, etc.)

2. Affective states as essential ingredients for cognitive information processing

For the past three centuries, two views of mind have been vying for supremacy. One view sees the conscious human mind as arising from the brain's symbol-manipulating abilities, not that dissimilar, in principle, from modern computers. If that view is fundamentally correct, then mind can be recreated through our ability to fathom the underlying computations, and we should be able to re-instantiate mind on non-biological platforms, such as digital computers, that can perform the needed calculations (i.e., supposedly "virtual minds" can be created on computers without worrying much about brain evolution and neuro-organic issues). In the classical cognitive-computational view, mind is independent of the type of device on which the relevant information is processed, and we should be able to construct minds symbolically without knowing the details of brains. Of course, there is also the more moderate school of "embodied cognitions" (e.g., Wilson, 2002) that strikes us as one way in which affective and cognitive issues can be organically integrated, especially if one recognizes how the brain was evolutionarily organized to control and regulate bodily functions. Another is the emerging discipline of cross-species affective neuroscience (Panksepp, 1998) that seeks to see BrainMind organization from a very explicit bottom-up vantage, without any attempt to marginalize developmentally emergent top-down controls.

In any event, adherents of computational neuro-mathematical idealism in cognitive theorizing remain enticed by the possibility that minds are created "merely" from the capacities of brains to process symbolic codes. Some extreme views of this type envi-

sion that brains may contain intrinsic symbol-processing capacities evolutionarily designed to extract important features such as "chairness" from environmental stimuli that allow us to recognize the infinite diversity of chairs in the world. According to certain cognitive views, the capacity of the brain to generate Higher Order Thoughts (HOTs) is a cardinal feature of consciousness (Matey, 2006; Rosenthal, 2002). Within that worldview, the capacity for subjective phenomenal experience may, in fact, be largely unique to the human species, except *perhaps* for a few other closely related primates. This has long been a prevailing, if not predominant, view in cognitive science. Of course, it is becoming clear that if we do not deal with animal emotions, we will never understand their minds, or for that matter, our own (Panksepp, 1998).

The minority position, ever increasing in influence, is a more "embodied" organic view, which accepts that minds are integrally linked to brains and bodies as well as the environments in which they operate (Smith and Gasser, 2005). In this view, infants are born with certain natural skills and proclivities to actively reach out and explore and to affectively engage their environmental circumstances (Meltzoff and Decety, 2003; Reddy, 2003). Adherents of this type of "naturalism" believe that we learn concepts such as "chairness" through our actions – our search for and satisfaction in finding places in the world where we can rest our sometime weary bodies. We learn language in part through our engagement with the 'musical' prosody of emotional sounds, allowing our affective-emotional nature to promote language acquisition (Panksepp, 2009, 2010).

In the social realm, we learn to negotiate emotional complexities through our active capacity to establish inter-subjective spaces where we mutually create the social texture of our lives through our ability to blend our affective desires with those who care about us. This view acknowledges the deep nature of our sense of agency, and our primordial desire, present in a rudimentary form at birth, to live life actively as opposed to simply being molded, as some still believe, by the ever-present reinforcement contingencies of the environment. In this view, nature has given us many tools to explore and confront the world and our capacity to experience affect informs us about what is good, bad and neutral in our environments. These feelings help guide our life choices and reinforce our learning (Lieberman, 2007; Young, 1943). In this view of mind, the capacity of the brain to generate affective feelings is the source of behavioral *reinforcement* and the primal source of consciousness – capacities we share with many other animals. In this view the efficacy of "rewards" and "punishments" in establishing learned behavioral control is based fundamentally on affectively guided learning processes, rather than just presently poorly specified "reinforcement" processes, which is largely a concept that covers over a great deal of our ignorance about how lower brain affective processes help regulate higher brain functions. Thus instead of 'reinforcement' creating emotions (Gray, 1990), affective-emotional changes may promote the process of reinforcement (Panksepp, 1990).

Of course, to be fair to computationalism, robotic researchers have recent returned to building more embodied insect-like architectures, and they are finding that when they in fact build in some basic emotional and motivational systems into their "bugs", many of the perennial problems of artificial intelligence engineering begin to dissolve (e.g., Dietrich, 2009). It is gratifying to see such convergences on basic life principles.

We also need to recognize that organismic BrainMinds are fully embodied, unlike digital computers, and the internal states of both body and brain are more than just informational content, but the substrates that create the coherence of organisms before they become captivated by the "cognitive" perceptual driven "movie in the head." Further, the "situated cognition" perspective has informed us that much of animal intelligence is not simply an intrinsic brain function, but also an outcome of dynamic perceptual linkages to 'information' already existing in the external world (Gigerenzer, 2008; Makin et al., 2008). Likewise, it would be wise to recognize that the brain's potential for generating core affective values, are not simply related to the objects of the world, but arise substantially from inherited brain activities that allow us to be in the world as coherent creatures (Panksepp, 1998, 2005). One of the critical keys to MindBrain understanding that will not be provided by cognitive perspectives is why our bodies and our worlds affectively feel the way they do.

Because of a vast neglect of affective-emotional processes during the recent "cognitive revolution" (Panksepp, 1988) one of the greatest remaining mysteries of the BrainMind is the fundamental nature of affective experience. How do mental functions arise from the higher order complexities of a fundamentally physiochemical world? How is it that animals experience the world in terms varieties of good and bad feelings – in terms of 'rewarding' and 'punishing' brain and world events? Cognitive science has largely remained silent about the many positive and negative feelings that arise from our bodies and brains interacting with the world. Indeed, there is still much resistance to discussing or discriminating the many distinct types of affects that help organisms control survival-promoting behavioral outputs.

As far as certain lines of brain research inform us, certain feelings of pleasure, pain and displeasure arise from our sensory-perceptual connections with the world (Berridge, 2000; Young, 1959) and from neural sensing what is happening within the body (Denton, 2006). There are yet other core affective feelings, from RAGE networks that can promote anger to PLAY circuits that can promote playful joy, to LUST filled sexual systems and those that promote nurturant CARE as well as separation-distress (PANIC/GRIEF). Unconditioned FEAR circuits may be essential for fear conditioning, and the entire array of distinct emotional circuits link to general purpose SEEKING networks that allow animals and humans to avoid harm and to harvest all the environmental rewards needed for survival (Panksepp, 1998, 2005). Affective feelings appear to arise from the way certain intrinsic emotional action and affective body-sensing abilities of our brains interact with our perceptions of the world. It would be a categorical error to call the intrinsic primary-process affect of the brain 'cognitive'. These are fundamental "states" of mind that guide and regulate cognitive formations.

Since such issues appear to be under-appreciated (perhaps largely because of historical forces that are rarely openly discussed: the animal mind seems scientifically inscrutable), let us re-emphasize: There are many distinct types of primitive affective experiences some linked to sensing the fruits and dangers of the world (e.g., the pleasure of taste and the pain of bodily injury), and clearly the affective and informational aspects of such systems diverge at the thalamic level, with the affective tone being integrated by subcortical neural functions while the informational (cognitive) aspects are more dependent on thalamocortical channel controls (Norgren, 1984). Some organic feelings are related to homeostatic states of the body (hunger and thirst, and their satisfactions) (Denton, 2006), while yet others seem to be intimately related to the diverse 'instinctual' (unconditioned) emotional actions systems of the brain (Panksepp, 1998). To understand how such affective feelings are created in human brain, we have no obvious empirical strategies other than to study corresponding, evolutionarily related processes in animal models (Lieberman, 2007; Panksepp, 1998, 2005) This makes behavioral-affective-social neuroscience an integrated discipline that has to consider many non-cognitive aspects of both unconscious and experienced mental processes. Behavioral neuroscientists should finally relax their traditional guard against psychological concepts, and accept that without the blending and integration of distinct cognitive, affective and motivational perspectives, we cannot generate a

coherent understanding for brain control of organismic actions. 'Cognitive' and learning concepts alone will not suffice.

3. How overuse and misuse of the cognitive concept may harm behavioral neuroscience

The previous sections highlighted ways in which cognition is used and gave examples with definitions and potential defining properties, and the need for additional viewpoints to conceptualize organisms as they truly are. An attempt was made to illustrate the potential by using these definitions or set of properties to 'overuse' the term meaning over-extend the concept in order to have it be all inclusive related to behavioral neuroscience goals. When this occurs there can be a dramatic decrease in the worth of the term because it becomes the same as the 'study of brain-behavior mechanisms' – a shorthand way of saying something very general. Likewise, 'motivation' is not a specific, single brain function but a conceptual label for a host of homeostatic systems that sustain bodily constancies as well as the shifting responsivities/sensitivities of sensory systems that are linked to bodily needs. Using general overarching conceptual terms is not necessarily harmful and can surely boost communication and progress, if there is consensus about what the terms actually mean. Our examples and many key human experiences lead us to another view concerning the debate among behavioral neuroscientists about what cognitive terms mean, namely that affects are equally important and distinct, and we suggest how the various types of brain functions should be categorized and parsed to enable each concept to play a clearer and more distinct roles in our visions of how brains produce minds and behaviors.

Another harmful characteristic besides overuse of cognitive terminology could be its often inappropriate use, leading to at least five different types of misuse: These include (1) relegation of a minor or subordinate role for other conceptually distinct psychological processes; (2) an over-reliance on the framework of 'top-down' processing to define how evolutionary levels of brain function interact; (3) Missing aspects of integration and an excessively holistic approach to understanding the causal factors underlying behavior; (4) Reducing the important influence of the properties of brain affective outcomes in energizing and guiding behavior; (5) Diverting attention away from brain-behavior relationships which may constitute the core of the affectively imbalanced states and impaired interpersonal relationships that characterize mental illness. Let us consider each of these in turn.

3.1. Needless battles among conceptual categories

One side effect of the tremendous emphasis on cognition and cognitive functions has been the neglect of other concepts used to describe brain-behavior processes. As noted, conceptual terms such as affects, emotions and motivation, once widely used in behavioral science and psychology, need to be restored into the balanced curriculum of behavioral controls. Emotion and affect have only recently been seriously entertained, with increasing acceptance, in behavioral neuroscience (see Panksepp, 1998; Panksepp and Biven, 2011). Despite the resurgence of psychological terms such as sensory, emotional and homeostatic affects as a way of explaining brain-behavior relationships (Berridge and Cromwell, 1990), there remain the urgent problems concerning the manner in which cognitions can be thought of as overriding thought-related process that control the more basic, and with ontogenetic development, increasingly subordinate processes. In our view, the bottom-up view that emphasizes affective-emotional processes is a key to early development, while the top-down view that emphasizes top-down processes, provides us a richer view of adult mental life.

Much research is focused on regulation of emotion by cognition and how inhibition of emotional behaviors is moderated by a cognitive gating mechanism (Ochsner and Gross, 2005). Another way of thinking about a function such as gating might be that there are qualitatively different levels of gating that occur that include both 'affective-emotional gating' and 'cognitive gating' with no level being more dominant than the other (Cromwell et al., 2008). Our recent work demonstrating that inhibitory gating circuits related sensory inputs is pervasive and located in established neural networks of emotion has supported this latter idea (Cromwell and Woodward, 2007; Cromwell et al., 2007, 2005; Mears et al., 2009). Of course, a case could be made that the above affect-emotion focused research can be simply deemed to be an extension of cognitive neuroscience (e.g., Lane and Nadel, 2000). For instance, the vast amount of research focusing on emotional conditioning (LeDoux, 1996) could be viewed as a 'cognitive' learning approach, but much of this work could be improved by focussing on the control functions of the primary process emotional states themselves (Panksepp, 2004), rather than just leaving them in a broad category of unconditioned responses. For instance, it is possible that the unconditioned responses (i.e., instinctual emotional arousals) are critical for FEAR conditioning to occur in the amygdala.

The link between conditioning and cognition is powerful and has been suggested to be an important cognitive process shared by diverse organisms with clinical implications (Pickens and Holland, 2004). Still, it was not long ago that Pavlovian or operant conditioning was also major components of motivational theories of animal and human behavior (Toates, 1986; McClelland, 1987). Thus, we must welcome conditioning research that recognizes the vital contribution of motivational and emotional mechanisms involved in how animal's learn to revalue stimuli following experiences with cues that predict new affective outcomes (Dickinson and Balleine, 1990).

3.2. The perennial battles between top-down cognitive and bottom-up neuroscientific approaches

We have already touched upon this grizzled but still contentious issue, one that may have broad implications when attempting to decipher new results of functional connectivity or activity coherence of neural activity (Ochsner et al., 2009). This issue involves the well-known frameworks of circuit flow of information between 'top-down' and 'bottom-up' directions. The bottom-up framework has been extremely useful is building models of communication networks and has provided useful insights into the important processes involved in attention, learning, memory and other information processing functions (Grossberg, 1999; Decety and Meyer, 2008). Thus, the bottom-up perspectives are not well accepted by individuals involved in cognitive neurosciences and it is not deemed a bona fide requirement as part of a cognitive model of brain function where emotions are often largely envisioned in cognitive terms (e.g., Lane and Nadel, 2000; Pessoa, 2008).

In our estimation, it is unwise to partition the models of mental (and neural) function into just top (dominant) and down (subordinate) aspects as if these relationships are strong and static (and persistent in the life-course). This type of implicit or explicit top-down perspective is probably not useful in many cases, especially in realistic views of organismic maturation, and may actually harm the development of more realistic models that incorporate dynamic properties and bidirectional interactive multi-way communications (Cisek and Kalaska, 2010). Recent data acquired using multi-site single-unit recording or from broad neuroimaging techniques supports the ideas that neural activity flows into multiple regions and there is great overlap in terms of event-related activity in a broad range of neural regions (Woodward et al., 1999; Gutierrez et al., 2010; Chow et al., 2009). It is probably fair to say

that the evoked consequences of many sensory signals (e.g., vision) can be monitored, to some extent, in every region of the brain. Theorists that take a more integrative approach to behavior such as hunger and feeding have proposed that the neuroaxis communication is highly dynamic and bidirectional (Grill and Hayes, 2009; Berthoud, 2004). It is hard to imagine it otherwise in any realistic neurodynamic sense. Still, we should not forget that in brain evolution, the earlier solutions provide a necessary foundation for higher functions to operate.

3.3. Holistic integrative network models

Another key issue, highly related to previous one, is the need to incorporate diverse factors into any model that provides possibilities for interactions between the brain and other parts of the nervous system. The 'Neuron Doctrine', important as it is, does not yet allow us robust linkages to global brain and behavioral functions, which require 'Network Doctrines' which recognize the specializations inherent in certain neural pathway functions. Likewise, a holistic body-inclusive approach toward behavior should include other systems besides the nervous system, in order to get more accurate and useful integrative views than any limited mental or brain model. The role of the body in emotional control is generally well recognized (Fosha, 2009) but not as well studied, and one has to see various psychological functions to have integrated brain and bodily components. For instance, in the emerging field of affective-fatigue studies, it is being recognized that there are peripheral fatigue factors as well as central ones (Roelands and Meeusen, 2010).

In general then, cognition has been a conceptual term, often limited by primarily focusing on the conceptual nervous system to develop mental models of behavior. Other terms such as emotion or motivation have made attempts at holistic approaches but have been historically linked to specific aspects of general physiology, peripheral signal transduction and homeostatic systems (James, 1894; Cooper, 2008). Extending explanatory concepts so that they naturally include multiple systems will obviously enable more complete explanations. For instance, recent work in the fields of psychoneuroimmunology or psychoneuroendocrinology supports the clear importance of understanding how immune cell signals or hormone levels could be important parts for why behavior is directed to potential outcomes. (Nelson, 2005; Graham et al., 2006, 2009). Cognition is not the term that naturally incorporates these diverse systems and by restricting our explanations to cognitive processes, there could be an undesirable neglect of such important bodily variables not only in our modeling of mental 'disorders' but also cognitive activities.

3.4. The role of affective valuation and evaluation in behavioral control

The fourth area of misuse deals with the neglect of affective outcomes (or the various 'rewarding' and 'punishing' feelings that exert behavioral control in both humans and animals) along with their potential predictive properties in cognitive models. Recent behavioral neuroscience work has shown that neural activity in diverse brain regions encode and potentially utilize outcome information (Watanabe et al., 2007; Cromwell and Schultz, 2003; Hollerman et al., 1998). The incentive motivational theory of behavior combines incentive properties with a diverse array of other properties including internal state information (Toates, 1986).

This type of diverse model that describes factors involved in the production of behavior allows for the outcome and its expectancy to be powerful mediators of choice behavior and goal-directed action. Cognition with restricted emphases on sensory transformations of input have relied primarily on higher-order information-processing to associate and create a decision, while the affective outcome has too often had a minor role in many of these models (Taylor, 2004; Pitt et al., 2002). New areas of study that include neuroeconomics have proposed novel ways to incorporate incentive processing, yet they are commonly limited because of the neglect of affective state influences (Glimcher, 2009).

3.5. Affective implication for mental health and psychiatric disorders

The final proposed misuse has significant implications for biomedical research and the search for appropriate animal models of mental illness. Mental disorders have a broad spectrum of symptoms that include alterations in learning, memory, attention, emotion and behavior (DSM-IVR). The multitude of symptoms has made it very difficult for professionals to agree on exact diagnostic criteria and the relative importance of different symptoms. We have previously made the case that it is imperative to focus on the core neuro-emotional alterations in psychiatric illness (Panksepp, 2004, 2010b). Without a change in these core processes, other functions such as learning or memory will not be enhanced. What are these core processes? It is proposed that they are primary process affects that arise from core emotional operating systems (Panksepp, 1998, 2004). This misuse of the term cognition can misdirect us in the search for core affective symptoms of psychiatric disorders as well as in that kind of translational approaches behavioral neuroscience should take in attempting to discover new ways to understand and treat mental illness (e.g., Alcaro et al., 2010; Zellner et al., 2011).

A most serious drawback of global use of cognitive terminology may be that it restricts the development of potentially more useful psychiatric models and may retard medication development in harmful ways. For instance, in areas such as feeding research, a focus on affective properties of appetite reducing drugs may be of critical importance for effective medicinal development (Panksepp, 2010c). Many of these issues were highlighted in a recent overview of current problems with research that is attempting to better categorize psychiatric disorders (Hyman, 2007). Steven Hyman, the former director of the National Institute of Mental Health suggested that the vast gaps between neurobiological and clinical approaches to understanding emotional disorders remain enormous. Manifesting a cognitive bias, he suggested they arise largely from (1) "the difficulty of characterizing the circuitry and mechanisms that underlie higher brain functions" while failing to note that many emotional difficulties may arise from imbalances in lower affective functions. He highlighted the evident (2) "complexity of the genetic and developmental underpinning of normal and abnormal behavioral variation" that prevents integration between diagnostic labels and brain problems (a serious problem indeed, if one does not consider the emerging bottom-up emotional features), and (3) "the unsatisfactory nature of current animal models of mental disorders" which we believe will remain the a case as long as investigators tend to focus on cognitive issues as opposed to tacking the underlying affective ones.

Still, Hyman recognizes, as should all of us, that practically all the major advances in medicine have relied on the insightful use of animal models to ferret out the biological sources of disease, and to evaluate new potential therapies before they are used in humans. Just consider the first modern medicine, insulin, introduced by Banting and Best in 1922. Once they had identified deficit in pancreatic insulin production in canine models of diabetes, they rapidly demonstrated that insulin supplementation could reverse the disease process. This knowledge rapidly saved and continues to save millions of children who would otherwise have died prematurely.

Most other medical advances could not have been achieved without animal models. Hyman's assertion about the "unsatisfactory nature of current animal models of mental disorders" is poignant from the context we have been exploring here. Most of these models have explicitly failed to even consider the changes in primary-process emotionality that have long been waiting in the wings to be used in preclinical research (Panksepp, 1998).

4. Ideas for the future

The future of behavioral neuroscience (not to mention the affective, cognitive and social neurosciences) is bright and there has been abundant growth and success in diverse research endeavors. Thinking about the brain and using terms such as cognition and cognitive has certainly fertilized useful discussions in the field, and has fostered understanding of memory formation and learning processes and how the brain can in some ways function like a computing device (Berger et al., 2010). This progress is indebted to the results of cognitive science and how various information-processing concepts in psychology have been translated to describe brain activity. Now there is general acceptance for brain functions as intervening variables that influence all behaviors, and a mere input–output analysis is no longer sufficient. Indeed, some of the evolutionarily designed "output" functions such as integration of emotional unconditioned responses, may be more involved in learning than most assume. Thus, it is periodically useful to reevaluate the ways we describe the factors that influence behavior in order to promote major leaps forward in the conceptual infrastructure of behavioral neuroscience. A review of these ideas and how cognitive concepts are currently used illustrate possible roadblocks that could be envisioned as overuse and, at times, misuse. Discussing these issues openly may provide greater clarity, cross-disciplinary integration, and more effective research in general.

One path to change is a better recognition of how we use the terms to describe brain-behavior relationships. To effectively apply the idea of cognitive processing it may be now appropriate to begin using narrower definitions, and better descriptions of processes that actually exist in brains rather than relying too heavily on concepts handed down to us from a pre-neuroscientific past. Philosophy has endeavored to discuss broad versus narrow definitions for cognition – for instance, Green (1996) has argued that cognitive is not as ambiguous as popularly thought and that the term can be used in a rigorous fashion, as long as one is clear about the domain of usage. His strict meaning is related to ethics in philosophy and *truth-evaluableness*; this way of thinking harkens back to the early usage of the term in psychology when belief systems and value were part of a larger cognitive-emotive system (Tolman, 1952; Asch, 1952; Festinger, 1957). Such a narrow definition, based on the philosophical study of ethics, may not be easily translated and applied to behavioral neuroscience, but other narrower views of what cognition should be deemed to be, could provide useful advances in conceptual clarity. For instance, it has been proposed that cognition does not involve all information processing but involves that information processing that includes primarily flexible behaviors as an output (Greene et al., 2004). This stricter vision of what cognition means entails a more constrained vision of how cognition accesses and enables different output paths to behavioral flexibility. Another way to develop a stricter definition is to develop in parallel, definitions for related psychological concepts. Previously, many researchers have divided the mental/psychological space into those processes that are cognitive and those that are affective. This partitioning could be made more clear and take into consideration the various types of affects (e.g., emotional, homeostatic and sensory), highlighting both the overlapping and non-overlapping associated processes, that can be dissociated and can interact (Ciompi and Panksepp, 2004).

Another important factor in the move toward a greater consensus will be to use the information that the neural and behavioral data provide to guide the development of terms and concepts that come into general use. Novel methods involved in neural and behavioral analysis have already uncovered the important dynamic properties of brain activity and are beginning to reveal the ways that functional connectivity can be understood (Sadaghiani et al., 2010). Using higher resolution neuroimaging and more specific ways to probe multiple regions of the brain during behavior (Pennartz et al., 2009; Goonawardena et al., 2009; Sanchez et al., 2005) will open up new ways to think about how the brain communicate between regions and how it incorporates signals from other systems. These new methods or new ways of using older techniques may not be best described in older conceptual terms. New terms may be needed that are not limited by the historical hindrances and ambiguities of the older ways of thinking. One example of a terminology that explicitly seeks to do that is the utilization of capitalized vernacular terms for labeling the primary-process emotional-affective networks of the brain – e.g., SEEKING, FEAR, RAGE, LUST, CARE, PANIC/GRIEF and PLAY (Panksepp, 1998, 2005). This can help minimize confusions with the vernacular meaning of such words, while retaining the heuristic-generative aspects of language needed for making novel predictions.

This review does not end with a the pronouncement of any new term or terms in this regard but concludes by stressing the need for a rethinking for the words that we use and how valuable and harmful they can be depending on how well, and clearly, we use them. For some, this argument may be about semantics or linguistic development but the debate will be important not only for the language chosen but what we actually mean by the words we use to describe the complex relationships between body, brain and the world, both genetically and epigenetically molded. Progress can be promoted and new directions created if we find agreeable ways to share language use patterns in ways that match the complexities of the BrainMind functions we are privileged to study. Operational definitions, arising from debates among the members of the Vienna Circle, were a great advance in establishing agreed-upon rules for describing how we measured things in which we were interested. Better agreement upon conceptual definitions, much harder to nail down among all interested parties, are now needed to advance scientific progress into MindBrain processes that are more subtle than we ever expected. And if such projects succeed, we may even eventually know what it means for the *process* of 'reinforcement' to have occurred in the brain, as we know how well the *procedure* of 'reinforcement' allowed learning and cognition research to flourish in behavioral neuroscience.

5. In sum

Disparate views of mind have been battling for primacy ever since Descartes divided mind and body, while his younger contemporary Spinoza pursued a rear-guard action, urging a more unified, fully embodied view. Our goal in this paper has been to promote such a rear-guard action that may better envision the complexities we must face in order to understand the mammalian BrainMind, not to even mention the diverse ways of other species. We feel confident, that our more recently evolved neural spaces for higher-order cognitive-conceptual abilities of an expansive neocortex remain profoundly anchored to more ancient affective state-control processes of the brain. Rather than having top-down or bottom-up perspectives seeking to prevail over each other, it is time to synthesize the best of each approach to better understand how the whole BrainMind is integrated into an adaptive-anticipatory organ that it is (for a fine development of this theme, see Northoff et al., in this issue).

To do this well, we cannot leave the affective feelings of other animals out of our discussions and cognitive equations, difficult as they may be to study compared to learning and memory. Convergent evidence indicates they are evolved processes of all mammalian brains. To achieve a more integrated understanding, we do need to parse brain and mind functions into various affective, attentional, cognitive and motivational processes, and to study how they interact. Just as many of us consider how ancient forms of simple learning (classical and operant conditioning) were antecedents for more recent cognitive developments, all of which remain grounded in diverse earlier solutions that have been globally called *unconditioned stimuli* and *responses* – brain processes essential for learning and more subtle higher cognitive processes such as decision making – that have not received the experimental attention they deserved in behavioral science.

Thus, our goal here was to facilitate a discussion that esteemed neuroscientists have long recognized as problematic in our field. Perhaps no one has said it better than Gyorgy Buzsaki (2005, p. 828): when he concluded from his studies of hippocampal theta oscillations "that our behavioral-cognitive terms are simply working hypothetical constructs that do not necessarily correspond to any given brain mechanism. Although the true goal of neuroscience research is to reveal how the brain generates behavior..., most behavioral-cognitive research, to date, seems to work in the opposite direction. We take a man-created word or concept... and search for brain mechanisms that may be responsible for the generation of this conceived behavior." Thus, we have a long way to go before we develop a lexicon that corresponds to the true functional organization of the mammalian brain.

References

Alcaro, A., Panksepp, J., Witczak, J., Hayes, D.J., Northoff, G., 2010. Is subcortical-cortical midline activity in depression mediated by glutamate and GABA? A cross-species translational approach. Neurosci. Biobehav. Rev. 34, 592–605.

Asch, S.E., 1952. Social Psychology. Prentice-Hall, Englewood Cliffs, NJ.

Baars, B.J., Gage, N.M. (Eds.), 2010. Cognition, Brain & Consciousness: An Introduction to Cognitive Neuroscience. Academic Press, Elsevier, Amsterdam.

Banich, M.T., Compton, R.J., 2011. Cognitive Neuroscience. Wadsworth, Belmont, CA.

Berger, T.W., Song, D., Chan, R.H., Marmarelis, V.Z., 2010. The neurobiological basis of cognition: identification by multi-input, multioutput nonlinear dynamic modeling: a method is proposed for measuring and modeling human long-term memory formation by mathematical analysis and computer simulation of nerve-cell dynamics. Proc. IEEE Inst. Electr. Electron. Eng. 98, 356–374.

Berridge, K.C., 2000. Measuring hedonic impact in animals and infants: microstructure of affective taste reactivity patterns. Neurosci. Biobehav. Rev. 24, 173–198.

Berridge, K.C., 2004. Motivation concepts in behavioral neuroscience. Physiol. Behav. 81, 179–209.

Berridge, K.C., Cromwell, H.C., 1990. Motivational-sensorimotor interaction controls aphagia and exaggerated treading after striatopallidal lesions. Behav. Neurosci. 104, 778–795.

Berthoud, H.R., 2004. Mind versus metabolism in the control of food intake and energy balance. Physiol. Behav. 81, 781–793.

Buzsáki, G., 2005. Theta rhythm of navigation: link between path integration and landmark navigation, episodic and semantic memory. Hippocampus 15, 827–840.

Chow, S.S., Romo, R., Brody, C.D., 2009. Context-dependent modulation of functional connectivity: secondary somatosensory cortex to prefrontal cortex connections in two-stimulus-interval discrimination tasks. J. Neurosci. 29, 7238–7245.

Ciompi, L., Panksepp, J., 2004. Energetic effects of emotions on cognitions-complementary psychobiological and psychosocial finding. In: Ellis, R., Newton, N. (Eds.), Consciousness and Emotions. John Benjamins, Amsterdam, pp. 23–55.

Cisek, P., Kalaska, J.F., 2010. Neural mechanisms for interacting with a world full of action choices. Annu. Rev. Neurosci. 33, 269–298.

Cooper, S.J., 2008. From Claude Bernard to Walter Cannon. Emergence of the concept of homeostasis. Appetite 51, 419–427.

Cromwell, H.C., Hassani, O.K., Schultz, W., 2005. Relative reward processing in primate striatum. Exp. Brain Res. 162, 520–525.

Cromwell, H.C., Klein, A., Mears, R.P., 2007. Single unit and population responses during inhibitory gating of striatal activity in freely moving rats. Neuroscience 146, 69–85.

Cromwell, H.C., Mears, R.P., Wan, L., Boutros, N.N., 2008. Sensory gating: a translational effort from basic to clinical science. Clin. EEG Neurosci. 39, 69–72.

Cromwell, H.C., Schultz, W., 2003. Effects of expectations for different reward magnitudes on neuronal activity in primate striatum. J. Neurophysiol. 89, 2823–2838.

Cromwell, H.C., Woodward, D.J., 2007. Inhibitory gating of single unit activity in amygdala: effects of ketamine, haloperidol, or nicotine. Biol. Psychiatry 61, 880–889.

Damasio, A.R., 1994. Descartes' Error: Emotion, Reason, and the Human Brain. Putnam, New York.

Danziger, K., 1997. Naming the Mind: How Psychology found its Language. Sage, New York.

Decety, J., Meyer, M., 2008. From emotion resonance to empathic understanding: a social developmental neuroscience account. Dev. Psychopathol. 20, 1053–1080.

Denton, D., 2006. The Primordial Emotions: The Dawning of Consciousness. Oxford University Press, New York.

Dickinson, A., Balleine, B., 1990. Motivational control of instrumental performance following a shift from thirst to hunger. Q. J. Exp. Psychol. B 42, 413–431.

Dietrich, D., 2009. In: Fodor, G., Zucker, G., Bruckner, D. (Eds.), Simulating the mind. Springer Press, New York.

Festinger, L., 1957. A Theory of Cognitive Dissonance. Row Peterson, Evanston, IL.

Fodor, J., 1998. Concepts. Oxford University Press, Oxford.

Fodor, J., 2000. The Mind Doesn't Work That Way: The Scope and Limits of Computational Psychology. MIT Press, Cambridge, MA.

Fosha, D., 2009. Positive affects and the transformation of suffering into flourishing. Ann. N.Y. Acad. Sci. 1172, 252–262.

Gardner, H., 1985. The Mind's New Science: A History of the Cognitive Revolution. Basic Books, Inc., New York.

Gigerenzer, G., 2008. Rationality for mortals: How people cope with uncertainty. Oxford University Press, New York.

Glimcher, P., 2009. Decision Making and the Brain. Macmillan, London.

Goonawardena, A.V., Robinson, L., Riedel, G., Hampson, R.E., 2009. Recruitment of Hippocampal Neurons to Encode Behavioral Events in the Rat: Alterations in Cognitive Demand and Cannabinoid Exposure. Hippocampus.

Graham, J.E., Christian, L.M., Kiecolt-Glaser, J.K., 2006. Stress, age, and immune function: toward a lifespan approach. J. Behav. Med. 29, 389–400.

Graham, J.E., Glaser, R., Loving, T.J., Malarkey, W.B., Stowell, J.R., Kiecolt-Glaser, J.K., 2009. Cognitive word use during marital conflict and increases in proinflammatory cytokines. Health Psychol. 28, 621–630.

Gray, J., 1990. Brain systems that mediate both emotion and cognition. Cognition Emotion 4, 269–288.

Green, C.D., 1996. Where did the word "cognitive" come from anyway? Can. Psychol. 37, 31–39.

Greene, J.D., Nystrom, L.E., Engell, A.D., Darley, J.M., Cohen, J.D., 2004. The neural bases of cognitive conflict and control in moral judgment. Neuron 44, 389–400.

Grill, H.J., Hayes, M.R., 2009. The nucleus tractus solitarius: a portal for visceral afferent signal processing, energy status assessment and integration of their combined effects on food intake. Int. J. Obes. (Lond.) 33 (Suppl. 1), S11–15.

Grossberg, S., 1999. The link between brain learning, attention, and consciousness. Conscious. Cogn. 8, 1–44.

Grossman, S.P., 1969. A neuropharmacological analysis of hypothalamic and extrahypothalamic mechanisms concerned with the regulation of food and water intake. Ann. N.Y. Acad. Sci. 157, 902–917.

Gutierrez, R., Simon, S.A., Nicolelis, M.A., 2010. Licking-induced synchrony in the taste-reward circuit improves cue discrimination during learning. J. Neurosci. 30, 287–303.

Heidbreder, E., 1945. Toward a dynamic psychology of cognition. Psychol. Rev. 52, 1–22.

Hollerman, J.R., Tremblay, L., Schultz, W., 1998. Influence of reward expectation on behavior-related neuronal activity in primate striatum. J. Neurophysiol. 80, 947–963.

Hyman, S., 2007. Can neuroscience be integrated into the DSM-V. Nat. Rev. Neurosci. 8, 725–732.

James, W., 1894. The physical basis of emotion. Psychol. Rev. 1, 516–529.

Kassel, J.D. (Ed.), 2010. Substance Abuse and Emotion. American Psychological Association, Washington, DC.

Kosslyn, S.M., Andersen, R.A. (Eds.), 1992. Frontiers in Cognitive Neuroscience. Bradford, CamBridge, Mass.

Lane, R.D., Nadel, L., 2000. Cognitive Neuroscience of Emotion. Oxford University Press, Oxford.

Lazarus, R.S., 1991. Emotion and Adaptation. Oxford University Press, Oxford.

LeDoux, J., 1996. The Emotional Brain. Simon_Schuster, New York.

Lieberman, M.D., 2007. Social cognitive neuroscience: a review of core processes. Annu. Rev. Psychol. 58, 259–289.

Makin, T.R., Holmes, N.P., Ehrsson, H.H., 2008. On the other hand: dummy hands and peripersonal space. Behav. Brain Res. 191, 1–10.

Matey, J., 2006. Two HOTS to Handle: The Concept of State Consciousness in the Higher-Order Thought Theory of Consciousness. Philoso. Psychol. 19 (2), 151–175.

McClelland, D., 1987. Human Motivation. Cambridge University Press, Cambridge.

Mears, R.P., Boutros, N.N., Cromwell, H.C., 2009. Reduction of prelimbic inhibitory gating of auditory evoked potentials after fear conditioning. Behav. Neurosci. 123, 315–327.

Meltzoff, A.N., Decety, J., 2003. What imitation tells us about social cognition: a rapprochement between developmental psychology and cognitive neuroscience. Philos. Trans. R. Soc. Lond. B: Biol. Sci. 358, 491–500.

Mesulam, M.M. (Ed.), 2000. Principles of Behavior and Cognitive Neurology. Oxford University Press, New York.

Neisser, U., 1967. Cognitive Psychology. Appleton-Century-Crofts, New York.

Nelson, R.J., 2005. Introduction to Behavioral Endocrinology. Sinauer, Sunderland, MA.
Norgren, R., 1984. Central neural mechanisms of taste. In: Darien-Smiht, I. (Ed.), Handbook of Physiology—the Nervous System III, Sensory Processes 1. American Physiological Society, Washington, DC, pp. 1087–1128.
Ochsner, K.N., Gross, J.J., 2005. The cognitive control of emotion. Trends Cogn. Sci. 9, 242–249.
Ochsner, K.N., Ray, R.R., Hughes, B., McRae, K., Cooper, J.C., Weber, J., Gabrieli, J.D., Gross, J.J., 2009. Bottom-up and top-down processes in emotion generation: common and distinct neural mechanisms. Psychol. Sci. 20, 1322–1331.
Panksepp, J., 1988. Brain emotional circuits and psychopathologies. In: Clynes, M., Panksepp, J. (Eds.), Emotions and Psychopathology. Plenum, New York, pp. 37–76.
Panksepp, J., 1990. Gray zones at the emotion–cognition interface: a commentary. Cognition Emotion 4, 289–302.
Panksepp, J., 1998. Affective Neuroscience. Oxford University Press, Oxford.
Panksepp, J., 2003. At the interface of the affective, behavioral, and cognitive neurosciences: decoding the emotional feelings of the brain. Brain Cogn. 52, 4–14.
Panksepp, J. (Ed.), 2004. Textbook of Biological Psychiatry. Wiley, Wiley Hoboken, NJ.
Panksepp, J., 2005. Affective consciousness: core emotional feelings in animals and humans. Conscious. Cogn. 14, 30–80.
Panksepp, J., 2008. Carving "natural" emotions: "Kindly" from bottom-up but not top-down. J. Theor. Philos. Psychol. 28, 395–422.
Panksepp, J., 2009. Primary process affects and brain oxytocin. Biol. Psych. 65 (9), 725–727.
Panksepp, J., 2010a. Evolutionary substrates of addiction: the neurochemistries of pleasure seeking and social bonding in the mammalian brain. In: Kassel, J.D. (Ed.), Substance abuse and emotion. American Psychological Association, Washington, DC, pp. 137–168.
Panksepp, J., 2010b. Affective neuroscience of the emotional BrainMind: evolutionary perspectives and implications for understanding depression. Dialogues Clin. Neurosci. 12, 389–399.
Panksepp, J., 2010c. The pleasures and pains of brain regulatory systems for eating. In: Dube, L., et, al. (Eds.), Obesity Prevention Handbook. Elsevier, Amsterdam, pp. 5–14.
Panksepp, J., Biven, L., 2011. Archaeology of Mind: The Neuroevolutionary Origins of Human Emotions. Norton, New York.
Panksepp, J., Moskal, J., 2008. Dopamine and SEEKING: subcortical "reward" systems and appetitive urges. In: Elliot, A. (Ed.), Handbook of Approach and Avoidance Motivation. Taylor & Francis Group, LLC, New York, pp. 67–87.
Pennartz, C.M., Berke, J.D., Graybiel, A.M., Ito, R., Lansink, C.S., van der Meer, M., Redish, A.D., Smith, K.S., Voorn, P., 2009. Corticostriatal interactions during learning, memory processing, and decision making. J. Neurosci. 29, 12831–12838.
Pessoa, L., 2008. On the relationship between emotion and cognition. Nat. Rev. Neurosci. 9, 148–158.
Pickens, C.L., Holland, P.C., 2004. Conditioning and cognition. Neurosci. Biobehav. Rev. 28, 651–661.
Pitt, M.A., Myung, I.J., Zhang, S., 2002. Toward a method of selecting among computational models of cognition. Psychol. Rev. 109, 472–491.
Reddy, V., 2003. On being the object of attention: implications for self-other consciousness. Trends Cogn. Sci. 7, 397–402.
Richter, C.P., 1947. Biology of drives. J. Comp. Physiol. Psychol. 40, 129–134.
Roelands, B., Meeusen, R., 2010. Alterations in central fatigue by pharmacological manipulations of neurotransmitters in normal and high ambient temperature. Sports Med. 40, 229–246.
Rosenthal, D.M., 2002. How Many Kinds of Consciousness? Consciousness Cogn. 11, 653–665.
Sadaghiani, S., Hesselmann, G., Friston, K.J., Kleinschmidt, A., 2010. The relation of ongoing brain activity, evoked neural responses, and cognition. Front. Syst. Neurosci. 4, 20.
Sanchez, J.C., Erdogmus, D., Nicolelis, M.A., Wessberg, J., Principe, J.C., 2005. Interpreting spatial and temporal neural activity through a recurrent neural network brain–machine interface. IEEE Trans. Neural Syst. Rehabil. Eng. 13, 213–219.
Searle, J.R., 1992. The Rediscovery of the Mind. MIT Press, Cambridge, MA.
Smith, L., Gasser, M., 2005. The development of embodied cognition: six lessons from babies. Artif. Life 11, 13–29.
Taylor, J.G., 2004. A review of brain-based neuro-cognitive models. Cognitive Process. 5, 199–217.
Toates, F.M., 1986. Motivational Systems. Cambridge University Press, Cambridge.
Tolman, E.C., 1952. A cognition motivation model. Psychol. Rev. 59, 389–400.
Watanabe, M., Hikosaka, K., Sakagami, M., Shirakawa, S., 2007. Reward expectancy-related prefrontal neuronal activities: are they neural substrates of "affective" working memory? Cortex 43, 53–64.
Wilson, M., 2002. Six view of embodied cognition. Psychon. Bull Rev. 9, 625–636.
Woodward, D.J., Chang, J.Y., Janak, P., Azarov, A., Anstrom, K., 1999. Mesolimbic neuronal activity across behavioral states. Ann. N.Y. Acad. Sci. 877, 91–112.
Young, P.T., 1943. Emotion in Man and Animal: Its Nature and Relation to Attitude and Motive. John Wiley and Sons, New York.
Young, P.T., 1959. The role of affective processes in learning and motivation. Psychol. Rev. 66, 104–125.
Zachar, P., 2006. The classification of emotion and scientific realism. J. Theor. Philos. Psychol. 26, 120–138.
Zellner, M.R., Watt, D.F., Solms, M., Panksepp, J., 2011. Affective neuroscientific and neuropsychoanalytic approaches to two intractable psychiatric problems: Why depression feels so bad and what addicts really want. Neurosci. Biobehav. Rev 35, 2000–2008.