Neuroscience and Biobehavioral Reviews 76 (2017) 187–215

Contents lists available at ScienceDirect

Neuroscience and Biobehavioral Reviews

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

Review article

Reconciling cognitive and affective neuroscience perspectives on the brain basis of emotional experience

Jaak Panksepp (PhD)[a], Richard D. Lane (MD, PhD)[b], Mark Solms (PhD)[c], Ryan Smith (PhD)[b,*]

[a] Department of Integrative Physiology and Neuroscience, College of Veterinary Medicine, Washington State University, Pullman, WA 99164, USA
[b] Department of Psychiatry, University of Arizona, Tucson, AZ, USA
[c] Department of Psychology, University of Cape Town, Rondebosch 7701, South Africa

ARTICLE INFO

Article history:
Received 15 March 2016
Received in revised form 22 July 2016
Accepted 14 September 2016
Available online 15 September 2016

Keywords:
Affective neuroscience
Cognitive neuroscience
Consciousness
Emotion
Cortex
Brainstem
Awareness

ABSTRACT

The "affective" and "cognitive" neuroscience approaches to understanding emotion (AN and CN, respectively) represent potentially synergistic, but as yet unreconciled, theoretical perspectives, which may in part stem from the methods that these distinct perspectives routinely employ—one focusing on animal brain emotional systems (AN) and one on diverse human experimental approaches (CN). Here we present an exchange in which each approach (1) describes its own theoretical perspective, (2) offers a critique of the other perspective, and then (3) responds to each other's critique. We end with a summary of points of agreement and disagreement, and describe possible future experiments that could help resolve the remaining controversies. Future work should (i) further characterize the structure/function of subcortical circuitry with respect to its role in generating emotion, and (ii) further investigate whether sub-neocortical activations alone are sufficient (as opposed to merely necessary) for affective experiences, or whether subsequent cortical representation of an emotional response is also required.

Contents

* Corresponding author at: University of Arizona, Department of Psychiatry, 1501 N., Campbell Ave., PO Box 245002, Room 7304B, Tucson, AZ 85724-5002, USA.
E-mail address: rssmith@email.arizona.edu (R. Smith).

http://dx.doi.org/10.1016/j.neubiorev.2016.09.010
0149-7634/

1. Introduction

When surveying the neuroscientific literature on the topic of emotion, one broad distinction (both at the level of methodology and of conceptual/theoretical frameworks) might be made between the approaches of "affective neuroscience" (Panksepp and Biven, 2012; Panksepp, 2011a, 1998a, 1982, 1981) and the "cognitive neuroscience of emotion" (e.g., Lane and Nadel, 2000). The term "affective neuroscience" (AN) is associated with a broad family of approaches to understanding the neural basis of emotion within animal models and linking these to studies of human emotion. This approach enjoys significant advantages associated with the ability to manipulate and record neural activity through invasive techniques (e.g., deep brain stimulation [DBS], pharmacological manipulations, targeted brain lesions, genetic alterations, direct neurochemical measures, etc.). It also suffers from various weaknesses, especially in its applicability to understanding the neural mechanisms of human emotion, due to (for example) possible neurobiological differences between humans and other animals and to the impossibility of gathering verbal reports from non-human animals. In contrast, the term "cognitive neuroscience of emotion" (CN) is mainly associated with non-invasive approaches (e.g., functional magnetic resonance imaging [fMRI], positron emission tomography [PET], electroencephalography [EEG], etc.) for investigating the brain basis of emotion that are ethically appropriate in studying humans. Relative to more invasive methods, such procedures are limited in the inferences their results typically warrant.[1] However, they can examine the degree of agreement between verbal reports and nonverbal behavioral expressions of emotion. They also benefit from the ability to study the human nervous system directly.

Perhaps not surprisingly, given the differences in methodology, the researchers associated with these two different traditions have developed somewhat discordant conclusions regarding the neural basis of emotion—particularly with regard to the experienced "feeling" aspects of emotion. As the conscious/unconscious processing distinction in human emotion is thought by many to be of particular relevance to understanding psychopathology (e.g., Smith and Lane, 2016), greater consensus about how the neural basis of conscious affective states and related cognitive changes are instantiated is of considerable importance. This is especially true when one considers the critical role of conscious emotion in mental disorders and the maladaptive behaviors that can result from emotional reactions that are not consciously experienced or understood. However, for greater consensus to be achieved regarding emotional experience between the human and cross-species neurosciences, it will be necessary for researchers to first come to an agreement regarding the appropriate physiological and behavioral measures one can use to infer the presence of conscious feelings in humans and other animals.

Therefore, in the present article, we will attempt to first spell out where the theoretical differences lie between the AN and CN approaches on these issues. In doing so it is important to first highlight that there is also disagreement *within* each of these broad theoretical perspectives, and therefore not all of the arguments made here necessarily reflect the views of other researchers in each respective field. However, we believe there is significantly greater consensus within CN and AN than between them, and thus the views presented below will attempt to focus mainly on the areas of greatest disagreement. For instance, AN holds that higher-order cognitive experiences are next to impossible to study in animal models, and CN often advances the view that affective experiences require the cortical brain regions associated with higher cognition. There has been little discussion of how such problems can be empirically resolved, and this paper aims to begin such a conversation.

In what follows, Jaak Panksepp (JP) and Mark Solms (MS) will represent the AN view while Ryan Smith (RS) and Richard D. Lane (RDL) will represent the CN view. In Part 1 (Sections 2 and 3), each pair of authors will present an outline of their own view and the empirical evidence supporting it. In Part 2 (Sections 4 and 5), they will offer a critique of the opposing view, posing questions to which their protagonists are invited to provide clarifying answers. In Part 3 (Sections 6 and 7), each pair will offer responses to the other's critique and questions. Finally, in Part 4 (Section 8), the authors will review points of agreement/disagreement and suggest possible empirical routes toward resolution, and ultimately toward a more unified understanding of how emotional feelings are realized within the mammalian brain.

2. Presentation of the AN perspective (JP & MS)

2.1. Rationale and genesis of a cross-species affective neuroscience approach

A scientific understanding of the neural *constitution* of affect cannot be readily achieved by human research alone, since many of the necessary causal manipulations are not possible by the standard scientific methods used in human research. It seems reasonable to adopt the working hypothesis that affect is a more ancient property of the brain than, say, reflective cognition and language. Since animal brains with a simpler organization are also more accessible for causal experimentation, we concluded that it would be most useful to study homologous forms of affect across the mammalian series.[2] Against this background, it became increasingly clear, especially through radical neo-decortication studies, that most primary affects, at least in raw (unconditioned) form – whether they be *homeostatic* (e.g. hunger and thirst), *sensory* (e.g. pain and disgust) or *emotional* (e.g. fear and attachment)—are neurologically constituted at the level of subcortical brain regions, and not cortical ones (e.g., Panksepp et al., 1994). It became equally clear that the neural

[1] It should be acknowledged, however, that the CN approach also involves some methods for studying emotion in humans that do allow for stronger causal inferences (although in a somewhat diminished manner relative to AN approaches). These include pharmacological manipulations, DBS, transcranial magnetic stimulation (TMS), and transcranial direct current stimulation (tDCS), as well as research based on naturally occurring lesions, neurodegeneration, and genetic or acquired neurological conditions.

[2] Many of the issues discussed here have relevance for non-mammalian species too (for example, periaqueductal grey [PAG]—which plays such a central role in the AN conception of affectivity – is present in all vertebrates, and even invertebrates exhibit conditioned place preferences for drugs that mammals self-administer and get addicted to (Huber et al., 2011)). However, we will limit ourselves to the discussion of mammals, for the reason that they share more of the brain structures implicated in human emotion (especially at subcortical levels, where primal emotional circuits are situated).

mechanisms for affect were largely confluent with those for consciousness as a whole (i.e. wakefulness and arousal). This applies to all mammals, including humans (Damasio et al., 2013, 2000; Feinstein et al., 2015; Merker, 2007; Panksepp, 2015a, 1998a; Solms and Panksepp, 2012). If one were to ask, what is the emotionally and affectively most concentrated consciousness generating area of the whole brain, the winning candidate must be the periaqueductal grey (PAG; e.g., see Panksepp, 1998a, 1998b). This region has the largest number of discrete emotions represented, and appears the most affectively sensitive, as determined by the lowest electrical currents needed to evoke negative and positive emotional behaviors and feelings (as measured by rewarding and punishing effects evoked by DBS). It is here, we have suggested, where affective consciousness – the core valenced states of mind – first emerged as a unified emotional-behavioral and affective-valuative process in evolution. This contrasts with traditional wisdom – actually prejudice – that the subcortical realm in isolation is unconscious. That is conventional, but in our opinion not consistent with the evidence (discussed further below) that the rewarding and punishing properties of subcortical DBS (our main measure of affective experience) survives radical neo-decortication.

Considering the phylogenetic age of the brain regions in question, and considering also the evolutionary conservation of the anatomy, physiology and connectivity of these regions, we inferred that affective consciousness goes far back in brain-mind evolution (Fabbro et al., 2015; Panksepp, 2015b; Feinberg and Mallatt, 2016). Of course we accept that the elemental subcortical sources of affectivity, which we envision as basic survival tools, are modulated and regulated by a diversity of higher brain processes. However, we believe that primary-process affectivity itself is fundamentally constituted at the subcortical level.

These – the basic claims of AN – immediately raise the thorny issue of animal consciousness. Our approach to this issue is best explicated with reference to the historical context within which AN arose, namely the 1960s, when "physiological psychology" (which later became known as "behavioral neuroscience") was still guided by behaviorist principles. The goal of behaviorist neuroscience was to understand the plasticity of behavioral strategies, as analyzed with rigorous experimental studies of animal learning and memory formation, guided by Thorndike's Law of Effect. This law stated that if certain behaviors are consistently followed by rewards, those behaviors increase, whereas if they are followed by punishments, they decrease.[3] The founders of AN were of the view that, stripped of behaviorist ideology, this law amounts to a Law of *Affect* (Panksepp, 2011b), which states that behaviors associated with positive (pleasurable) feelings are likely to be repeated, while behaviors associated with negative (aversive) feelings are likely to decrease. In other words, we started from the assumption that "rewards" are rewarding because they *feel* good. In contrast to the behaviorists, AN approaches using electrical DBS that evokes various distinct emotional behaviors and sustains rewarding and punishing effects, led to the conclusion that valenced feelings exist, even in non-speaking animals, despite the obvious fact that researchers cannot see them. This is of course definitional of feelings (they are felt, i.e. subjective), but it was proposed that the distinct unconditional behaviors evoked by DBS could be a guide to the more specific nature of the feelings. Since the counter-assumption that one only has evidence of one's own feelings (because one can only observe subjectively one's own mind) is patently absurd, we adopted the hypothesis that feelings in animals may be *inferred* from physiological and behavioral evidence. There is a clear path for scientific consensus on this philosophical conundrum: unless and until evidence is produced which falsifies predictions arising from the hypothesis, we hold it to be provisionally true, especially if new and beneficial clinical interventions in humans can be identified on the basis of the hypothesis (e.g., Panksepp, 2016, 2015a). This approach applies equally to humans and other animals, the only difference being that we can infer human feeling states from speech behavior alongside all the other evidence (please note: we still cannot *directly* measure the feelings themselves, not even in humans). Clearly there are conundrums, but they are scientifically tractable.

The role of affect in Thorndike's "law of effect" seemed obvious. But during the 20th century, discussion of such invisible psychological processes – not only in animals – was discouraged if not forbidden (i.e., research along those lines was not funded or published). Concepts of "drive" (reflecting bodily homeostatic imbalances) and "incentive" (the worldly objects needed for survival and reproductive success) were acceptable concepts, so long as such theoretical terms were strictly operationalized. For instance, bodily drives could be operationally defined in terms of hours of deprivation of relevant nutrients or other "rewarding" objects in the world. But concepts denoting subjective states such as "hunger" in animals were typically purged in the major journals. "Incentives" could likewise only be defined in terms of the *quality*, *quantity* and *delay* of rewards that could promote learning, as with brain-stimulation reward (Trowill et al., 1969) even though *quality* was defined circularly.

To the present day, it is still the case that animal energy-balance and feeding research rarely uses affective concepts. This has substantive scientific implications, especially if *subjective feelings actually do exist* in other animals, and more so, if such brain dynamics *really have causal effects on behavior*. (For a discussion of how such naturalistic concepts could enhance the quality and utility of preclinical modeling in HUNGER research, see Panksepp, 2010b). But the behaviorist ideology prevails no longer. Thus, for example, according to Denton et al. (2009, p. 500) "there are two constituents of a primordial emotion—the specific sensation which when severe may be imperious, and the compelling intention for gratification by a consummatory act. They may dominate the stream of consciousness." This is truly a new era.

2.2. The emergence of potentially acceptable affective (mental) constructs in animal brain research and the implications for psychiatry

The first annual meeting of the Society for Neuroscience (SFN) was held in 1971. Panksepp presented his work on hypothalamic metabolic short-term control of feeding and long-term regulation of energy balance (Panksepp, 1972). Two years later he used the term "hunger" in discussing brain appetite controls in animal models (Panksepp, 1974). This marked the beginning of a radical departure with convention in the field, heralding the explicit conviction, for a vocal minority, that certain affective states of mind could be objectively studied in animals (for a history of the field, see Panksepp, 2010a).

This is not a purely terminological matter. It has practical consequences. If the term "hunger" is not used in animal research, might that not delay the discovery and development of hunger reducing medications for human weight problems? Likewise, might not the absence of *affective* animal modeling of human psychiatric disorders, like depression, delay the development of more effective psychiatric treatments, explaining the ongoing failure of pre-clinical animal modeling to yield truly new treatments in biological psychiatry (Panksepp, 2012)? AN has sought to counter that bias explicitly (most recently in Panksepp, 2015a, 2016).

[3] The formal wording of the Law of Effect was: "responses that produce a satisfying effect in a particular situation become more likely to occur again in that situation, and responses that produce a discomforting effect become less likely to occur again in that situation" (Thorndike, 1911).

When the major tranquilizer chlorpromazine came on the market in 1954, followed soon by antidepressants (MAO-inhibitors and tricyclics), followed by antianxiety agents (benzodiazepines), they were all discovered by chance rather than by scientific understanding of the brain mechanisms of affective sentience. Behavior-only animal modeling has yielded few new psychiatric medicines since that time. Why? We would suggest (Panksepp, 2010a; Solms and Panksepp, 2010) that failure is attributable to the fact that discussion of affective feelings in animals is still considered "tavern talk" which should be excluded from rigorous scientific discourse (see Footnote 3, p. 37 in Panksepp, 2005).

2.3. The scientific yield of a cross-species affective neuroscience: paths toward a scientific understanding of homologous primal human affects

This historical snapshot sets the stage for our present discussion. Leaving aside *homeostatic* and *sensory* affects (vide supra), which are less significant for psychiatry, there are at least seven evidence-based primal emotional tendencies that can be evoked from mammalian brains with deep brain stimulation (DBS) with proposed feelings (*in parentheses*). These are: SEEKING (*enthusiastic interest*), RAGE (*anger*), FEAR (threat-induced *anxiety*), LUST (passionate *sexual arousal)*, CARE (devoted *nurturance*), PANIC (the psychological pain associated with *separation distress*), and PLAY (prosocial *joy*).[4] All these DBS evoked states are rewarding (SEEKING, LUST, CARE and PLAY) or punishing (RAGE, FEAR, PANIC); see Panksepp (1981, 1982, 1998a) for detailed early reviews. Such effects (including related place preference/avoidance measures, along with neurochemical manipulations) are our empirical measures of feelings. That is, distinct emotional actions are evoked by site-specific application of unpatterned electrical energy across all mammalian individuals and species that have been studied, which affirms their unconditioned inborn (instinctual) nature. The fact that such evoked states are uniformly rewarding and punishing speaks to their subjectively valenced ontology. In reaching these conclusions, we simply followed standard scientific methodology: (i) we *hypothesized* that animals feel fear (for example), as do humans, in similar situations using the same brain systems, and (ii) we therefore *predicted* that when animals initially freeze and then flee in response to DBS of certain brain regions, they are having homologous emotional feelings to what humans experience during comparable brain stimulations (e.g., Panksepp, 1985) and that, when given a choice, animals (like humans) will therefore escape and avoid such brain stimulations in the future. When such predictions are confirmed, the hypothesis of animal feelings is confirmed (it remains *unfalsified*). Congruent emotional feelings reported verbally by humans following homologous stimulation (e.g., Heath, 1996; Panksepp, 1985) are of course critical for such translational conclusions.

It was the initial discoveries of subcortically induced rewards (Olds and Milner, 1954) and punishments (Delgado et al., 1954), with affirmation in human trials (see Heath, 1996 and Panksepp, 1985; for reviews), that prompted these cross-species, scientifically heuristic translations in the first place. Naturally, we do not rely on DBS alone; we have also worked extensively with focal lesions and pharmacological probes, in both animals and humans (with clinical predictions), and we have thereby greatly enhanced our understanding of the anatomy and physiology of the basic emotion command systems—and their novel implications for psychiatry (for most recent reviews, see Panksepp and Biven, 2012; Panksepp and Yovell, 2014; Panksepp, 2016, 2015a, 2004; Panksepp et al., 2014).

Why do we claim that the raw affects in question are essentially sub-neocortical processes? Firstly, the seven rewarding and/or punishing emotional affects/effects enumerated above are reliably evoked by DBS at subcortical sites and no such effects are observed at neocortical sites. These deep subcortical systems are highly overlapping (presumably interactive) in many brain regions (e.g., PAG, medial forebrain bundle [MFB], amygdala, bed nucleus of stria terminalis, septal regions, etc). It is noteworthy that the few studies that claim to have found "unconscious" affective changes with subliminal presentation of emotional-cognitive stimuli in humans, presumably mediated by cortical systems (e.g., Winkielman et al., 2005), may have not used sufficiently sensitive dependent measures (see Shevrin et al. (2012) for a study where *totally* "unconsciously" presented emotional words—below absolute detection limits for anything having passed the visual field—evoked measureable affective shifts in humans). There are also studies showing that external visual emotional stimuli presented at levels that do not reach cognitive awareness (as measured by self-reports) can significantly modify affective feeling (Tamietto and de Gelder, 2010). Simply put: stimuli that are *cognitively* unconscious can evoke measurable shifts in affective consciousness.

Indeed, natural (instinctual) emotional response states are only obliterated with large lesions localized to specific subcortical brain regions. In contrast, surgically decorticated neonatal animals retain these abilities—they are *highly emotional organisms* (for extensive summary of earlier decortication work, see Dror, 1999) and they still display all seven basic emotional action patterns. Likewise, hydranencephalic human children (born with little to no functional cortex) exhibit all seven instinctual emotional responses (Merker, 2007; Shewmon et al., 1999)[5] and massive neocortical damage does not block rewarding subcortical effects of DBS (e.g., Huston and Borbely, 1974, 1973; Valenstein, 1966) nor even complex emotional behaviors such as rough-and-tumble play in rats (Panksepp et al., 1994). In general, neonatally decorticated rats exhibit all "instinctual" motivated and emotional behaviors. Further, the drugs that excite and inhibit these same effects act upon receptor sites that are most densely located in subcortical structures. Such observations meet the standard neuropsychological criteria for double-dissociation of function—in this case between cortex and subcortical regions. The abundant empirical evidence for these conclusions is detailed elsewhere (Panksepp, 2011a, 1998a; Solms and Panksepp, 2012; Solms, 2015).

This is not to say that subcortical DBS, lesions, and drugs have no emotional effects in cortex. Naturally, the behaviors and feelings produced by the systems in question are powerfully elaborated and modulated by cortex, perhaps especially in humans. But preliminary results from an ongoing study we are currently conducting illustrates our main point: drugs which excite and inhibit the SEEKING and PANIC systems, with low doses of psychostimulants and opiates for example, produce almost comically variable cognitive-affective self reports in normal human subjects (Pantelis & Solms, in preparation).

Regrettably, traditional electrical and chemical DBS in animals that yield rewarding and punishing effects still need to be studied with stimulus-discrimination procedures to determine if animals can distinguish the various positive and negative affective sites from each other.[6] In this context, it is critical to remember that

[4] See Panksepp (1998a,b) for empirical details and references. We capitalize the basic emotions, as a proposed terminological convention to designate primary-process (evolved) brain emotional and motivational behavioral/affective systems (most emotional ones identified with DBS), to avoid mereological fallacies (part-whole confusions), and thus to distinguish them from related common vernacular usages (which are provided in italics).

[5] For another interesting adult case, see Feuillet et al. (2007).

[6] This requires animals to discriminate among different positive and negative affective states which have been very little investigated (e.g., Stutz et al., 1974). With

electrical-current thresholds for evoked emotional behaviors routinely increase as one moves rostrally in the neuraxis; thus one never evokes such emotional behavioral coherences, nor rewarding or punishing effects, from DBS of neocortex. AN is largely based on such studies, which admittedly have various interpretive qualifications and shortcomings, as do all neuroscience techniques. However, the fecundity of our approach has been affirmed by the development of new conceptualizations and treatments of various psychiatric disorders, including autism (Bouvard et al., 1995; Burgdorf et al., 2013; Sahley and Panksepp, 1987), ADHD (Panksepp, 2007a), addiction and depression (Panksepp and Yovell, 2014; Panksepp et al., 2014; Watt and Panksepp, 2009; Yovell et al., 2016; Zellner et al., 2011).

Clearly, the role of subcortical animal emotional systems in the modeling and understanding of human psychiatric disorders, and the search for new evidence-based treatments, can be greatly facilitated by research that pursues causal studies of the underlying neurobiologies of the instinctual (sub-neocortical) emotional infrastructure of mammalian brains (Panksepp, 2016, 2015a,b). This said, we recognize that a more recent variety of human-specific affective neuroscience has emerged largely from technological advances permitting *in vivo* functional human brain imaging. Although much of that research, in our estimation, highlights the cognitive-learned "representations" that *accompany* raw affects, here we simply note that it is remarkably difficult to use those correlative procedures to ferret out what is fundamentally due to the affective (unconditional) aspects of experience vs. the cognitive (conditioned) aspects, unless more temporally appropriate PET studies are deployed where people are allowed to fully *experience* strong-sustained emotional states during the brain imaging (e.g., Damasio et al., 2000). Overall, fMRI is simply less suitable for studying sustained affective states. For instance, when affective changes are monitored offline (after scanning) positive correlations are high with subcortical arousals, but when affects are measured online (i.e., while actually imaging brain responses to emotional faces) they are positively related more to cortical than subcortical arousals (Northoff et al., 2009). This suggests that cognitive appraisals made during the ongoing course of fMRI may contaminate the intended measures of affective shifts with the ongoing cognitive appraisals. After all, when cognitive activities are high, they transiently inhibit subcortical affective arousals, and without higher inhibition, emotionality in animals is increased (decorticate rage is a case in point, see Dror, 1999 for overview). Studies of brain-damaged patients also allow us to conclude that many cortical regions previously thought to mediate affective feeling states are actually doing something else, like cognitively inhibiting and regulating them (e.g., Damasio et al., 2013; Feinstein et al., 2015). Thus, for example, lesions in the prefrontal cortical regions responsible for "representing" affective states actually result in increased (not decreased) raw affectivity, although damage to orbitofrontal and cingulate cortices can reduce emotion recognition and the declared intensity of emotional arousals (e.g., Hornak et al., 2003). In any event, all of the basic emotional processes described by AN survive radical neodecortication of rats soon after birth (e.g., Panksepp et al., 1994), although such animals are of course deficient in learning (Deyo et al., 1990; Kolb and Tees, 1990). Whether neocortical structures are able, on their own, to *generate* affective feelings thus remains questionable, though we have no problem with the idea that many phylogenetically older archi- and paleo-cortical brain regions may instigate and regulate diverse affective states in various ways. Even neocortical regions may be programmed (through learning) to have affective functions by the more ancient emotional processes, and thereby participate in complex affectively based decision-making.

Actually, from the AN perspective, neocortex has few genetically determined functions at all, and is largely a *Tabula rasa* at birth, a random access memory space ready to be programmed by the confluence of sub-neocortical affective arousal functions and life experiences arising from diverse exteroceptive sensory inputs. This is consistent with the fact that the massive early developmental expansion of human neocortex, above that found in living anthropoid apes (chimps, gorillas & orangutans), is largely controlled by very few genes (Florio et al., 2015), which leaves little room for hardwiring of intrinsic functions. Almost everything in neocortex is apparently programmed by extra-cortical inputs. We have long known that even cortical vision is a learned process (Sur and Rubenstein, 2005). In analogous fashion, the cortex may learn to *know* emotions, and have thoughts *about* or promoted *by* emotional arousals; but this is all something quite different from primary emotional affect *generation*.

It is still widely believed (on purely conventional grounds) that the neocortex is "the organ of consciousness", but that belief has long been contradicted by abundant data (Merker, 2007; Panksepp, 1998a; Solms, 2015; Watt and Pincus, 2004). Our own view is that cortical consciousness is secondary, contingent and dependent upon activation by the same subcortical systems that generate affectivity. Indeed, many developmentally programmed cortical processes arise from the dynamics of subcortical affects, which subsequently can regulate affective processes (even to the point of repressing them into unconsciousness). From a developmental perspective, perhaps cognitive consciousness is permitted/promoted by *stabilized affectivity*, i.e. that consciousness itself consists in subjective feeling states that secondarily program and activate cognitive representations—which are unconscious in themselves. In short, there can be no objects of cognitive consciousness without the presence of an affectively conscious subject (for details see Solms and Panksepp, 2012; Solms, 2016).

2.4. Conclusion

Our position is that in order to fathom the primal (unconditional) nature of affective experiences, the most promising strategy is to work out the homologous affect generating neural detail in animal models. The relevant circuits in humans are not readily amenable to constitutive neuroscientific research. Abundant clinical implications will arise from a judicious blend of preclinical research that takes core emotional-affective processes of animal brains seriously, combined with correlative evidence emerging from diverse human studies, leading hopefully to novel approaches for better human psychiatric therapeutics (Bouvard et al., 1995; Panksepp and Yovell, 2014; Panksepp, 2016, 2015a; Panksepp et al., 2014; Solms, 2015). This said, it needs to be emphasized that higher-order forms of cognitive consciousness (explicit conscious [reflective] awareness of one's affective states) requires abundant higher brain processing, much of which may be unique to anthropoid apes, especially humans (e.g., as best reflected in our symbolic arts, music and literature). In short, many of the higher neocortical influences and regulations of emotionality are learned rather than intrinsic (evolved) functions of the brain. Unlike LeDoux (2012), we think many emotional and motivational (e.g., hunger and thirst) subcortical emotional "survival systems" are the generators of diverse affective *feelings*. We accept that cortical encephalization, and social learning, allowed affective states to be cognitively complexified and re-represented in all species

more recent light-stimulation procedures afforded by optogenetics as well as viral insertion of artificial receptors into neuronal subtypes in specific brain regions, one can stimulate those regions through peripheral administration of receptor agonists, offering the grand potential of DREADD (Designer Receptors Exclusively Activated by Designer Drugs) approaches to localized brain stimulation (Urban and Roth, 2015). Such technologies provide the possibility of a more detailed 2nd generation of cross-species affective neuroscience research (Anderson, 2012; Boly et al., 2013; Tovote et al., 2015).

in approximate proportion to the level of encephalization. (See Section 5 for the CN view's critique of this perspective.)

3. Presentation of the CN perspective (RS & RDL)

We will focus on four broad themes:

1. The degree of phylogenetic continuity across mammalian species in the organization of neural systems associated with "basic" emotions (e.g., sadness, fear, anger, happiness), and what this may entail about conscious access to emotions in humans and other mammals.
2. The neural basis of emotion generation, and the specific roles played by cortical and subcortical structures in that process.
3. The necessary and sufficient conditions for conscious access to emotions at both cognitive and neural levels of description.
4. The role of language, concepts, and thought in conscious and unconscious emotion.

3.1. Degree of phylogenetic continuity

From the CN perspective, there is considerable phylogenetic continuity between humans and other mammals. It seems reasonable to expect that fitness-related problems which humans and other mammals share (and which emotions function to solve) will tend to have been conserved. This leads one to expect that very similar mechanisms ought to be in place for these basic mammalian adaptive challenges, which we take to include things like responses to predator detection and related threats (i.e., fear), loss of basic fitness-enhancing resources (i.e., sadness, grief), and so forth (the neural circuits that evolved to generate these types of conserved responses have been termed "survival circuits"; LeDoux, 2012). However, human evolutionary history also very likely involved adaptive challenges whose solutions involved emotion, but that are not shared with many other mammals. Some relevant contenders here might involve phylogenetically newer emotions (and associated survival circuits) that function to guide successful navigation of hierarchical social groups (e.g., guilt, contempt, pride), and some morality- or social status-related variants of sadness and anger (Haidt, 2012). There is good evidence that the social groups of humans are larger than those of non-human primates, and that neocortical size correlates with the size of typical social groups (Dunbar, 2010). Perhaps certain other social primates share some of these mechanisms, but the question is unsettled, and differences in evolutionary history make plausible the idea that human emotional mechanisms may differ from those in other animals in important ways. It strikes us as possible that even subcortical emotion circuitry could have been co-opted to some degree to serve novel functions within hominid evolution. Therefore, from the CN perspective, the neural basis of human emotion may reflect commonalities as well as important differences when compared to animal models that reflect common and unique aspects of the evolutionary histories of each.

3.2. Emotion generation

The term "emotion generation" can be understood to involve mechanisms that function to automatically detect ("appraise") emotionally relevant properties of an organism's environment (as it pertains to the needs, goals and values of the organism in question), as well as mechanisms which trigger "emotional reactions" in response to the detection of such properties. Emotional reactions are in turn understood to be multifaceted, including peripheral physiological, behavioral, phenomenological and cognitive aspects. The human brain also appears to reflect this multifaceted nature in various ways. Some brain structures appear to "appraise" the perceptual/conceptual representations we have of our current situation (or those of situations we remember or imagine) in terms of emotional relevance; these same structures (and others they interact with) also subsequently trigger adaptive cognitive, peripheral physiological, and behavioral changes in response. Subcortical structures such as the amygdala, for example, appear to initiate cognitive and physiological changes in response to representations of simple perceptual features of a given situation (e.g., those highly predictive of threat); this occurs in part by interaction with cortex and in part by interaction with other survival circuit structures (e.g., the PAG) lower in the neuraxis (LeDoux, 2012; Whalen et al., 2004). However, at least in humans, higher cortical structures such as the ventromedial prefrontal cortex and dorsal anterior cingulate cortex may also appraise a situation in terms of more complicated cognitive constructs (e.g., goal-congruence), and trigger emotion-related autonomic reactions in response (Brosch and Sander, 2013; Critchley et al., 2003; Roy et al., 2012). The dorsomedial prefrontal cortex (DMPFC) also appears to play a role in emotion generation (Kober et al., 2008). Thus, in the human brain, both low-level subcortical as well as more cognitively complex cortical processing may appraise emotional relevance and/or act to initiate appropriate emotional reactions. In animal models it is clear that many of these lower-level subcortical "appraisal and emotional reaction-initiating" mechanisms are present; however, it is unclear at present whether the higher cortical emotion generation mechanisms exist and can be appropriately studied in animals. The presence of, and degree of complexity in, certain cortical emotion generation mechanisms may thus represent one important difference between the human and non-human emotional brain from the CN perspective.

In addition, it is important to highlight that, from the CN perspective, the emotional reactions generated by the survival circuit mechanisms described above need not correspond in a 1-to-1 fashion to the emotion concepts/words that are typically used to describe those reactions. In other words, emotion categories like "sad" or "angry" need not each map onto a single type of cognitive/bodily reaction or to a single neural circuit/system for generating it. Instead, as described in detail elsewhere (Barrett et al., 2011, 2007b; LeDoux, 2012; Lindquist and Barrett, 2008; Wilson-Mendenhall et al., 2011), emotion categories can be applied to different cognitive/bodily reactions in different contexts—and these different reactions can be mediated by different cortical/subcortical circuits. For example, different neural circuits may initiate different types of defensive reactions in different contexts, and yet a person might describe many of these defensive reactions as corresponding to the same category of "anger" (LeDoux, 2012). In addition, the same automatic reaction can sometimes be described/categorized as a different emotion in different situations, based on the presence of different contextual cues (Barrett et al., 2011). Therefore, when using "basic emotion" terms (e.g., sadness, fear, happiness, and anger, or RAGE/anger, FEAR/anxiety, PLAY/joy), the CN perspective understands these terms to refer to learned conceptual categories that are variably applied to automatic emotional responses (where these learned categories can also vary by culture); these terms therefore need not refer to specific emotion generation circuits (e.g., there need not be one "sadness circuit," one "fear circuit," and so forth) and, when specific circuits are activated, they do not necessarily always result in the same feeling state.

3.3. Conscious access to emotion

Considerable evidence in cognitive psychology generally (e.g., Dehaene et al., 2006; Hassin et al., 2005), as well as in the study of human emotion specifically (Kihlstrom et al., 2000; Lane, 2008; Lane et al., 2015b; Smith and Lane, 2015; Winkielman and Berridge,

2004; Smith and Lane, 2016; Smith et al., 2016), suggests that cognitive processes and emotional responses can take place unconsciously. With regard to emotions specifically, this evidence takes the general form of observations that, despite a verbally reported lack of awareness that a given emotional reaction has been consciously felt, certain behavioral, peripheral physiological, and/or cognitive reactions can be reliably triggered that are consistent with a given emotional state (and under environmental conditions that would be normatively likely to cause that emotion). There are also clinical phenomena, such as alexithymia or affective agnosia (e.g. associated with somatization), in which subjects report not feeling emotion despite their reporting somatic complaints that are consistent with an emotional response to a disturbing life circumstance with no other detectable organic cause (Lane et al., 2015b; Shipko, 1982; Stonnington et al., 2013; Taylor et al., 1992).

There now also exist multiple related and empirically supported models attempting to account for the difference between conscious and unconscious processing within cognitive science and philosophy (Baars, 2005; Dehaene, 2014; Morsella et al., in press; Morsella, 2005; Prinz, 2012). One very useful and empirically tractable notion is that of "access consciousness," or the ability for neurally represented information to be poised for use in goal-directed deliberation and verbal reporting (Block, 2005, 1995). Within the general framework of the aforementioned models, gating mechanisms are in place that selectively allow some active neural representations to be "broadcast" or "routed" (Zylberberg et al., 2011, 2010) to a broad frontal-parietal control network associated with sequential, goal-directed deliberation and action selection (Andersen and Cui, 2009). Only when selectively "routed" to this network can those representations be maintained/manipulated within working memory (Dehaene, 2014), and also integrated together to resolve conflicts between competing control processes in guiding deliberative action selection (including actions involving verbal reports; Boly et al., 2013; Morsella, 2005; Morsella et al., in press; Tononi and Koch, 2015). If an active neural representation is not made "access conscious" by being selectively broadcast within this network, its associated content/phenomenology will not be verbally reportable, nor will it be capable of guiding the selection of other such controlled, goal-directed actions (See Fig. 1). However, the active state of that unconscious representation may still be detected indirectly via the subset of that representation's downstream effects that do not depend on the aforementioned gating mechanisms. In the case of an unconsciously represented emotion, for example, such a representation may still be capable of causing automatic facial expressions, skin conductance changes, certain priming effects, gestures, script-guided action sequences, and possibly much more,[7] even in the absence of being made access conscious (and therefore without being verbally reportable). Evidence from cognitive neuroscience more broadly (e.g., from the psychological refractory period paradigm; Sigman and Dehaene, 2005) also suggests that the vast majority of processes and representations realized within the brain remain unconscious, and that only one "chunk" of represented information can win the competition for conscious broadcasting at any given moment (Dehaene et al., 2006).

It is noteworthy that some have suggested that experiential aspects of consciousness – "phenomenal consciousness" (or "qualia") – might occur in the absence of access consciousness (Block, 2005, 1995). However, others have instead argued that, to remain an empirically testable claim, phenomenal consciousness would need to at least depend on a given representation being modulated into some minimal state of "availability" to be selected for maintenance within the frontal-parietal working memory system, such that, *had it been maintained*, the subject could have reported being conscious of it (Prinz, 2012, 2007). Stated another way, if no evidence exists that can, at minimum, justify the inference that a subject *would have* been able to (verbally or nonverbally) communicate the presence of a conscious experience of a given type, then claims with regard to phenomenal consciousness would become empirically unfalsifiable. Recent arguments have thus been made that the qualia/phenomenology associated with a given representation (including representations of emotions and other bodily feelings) in fact emerges when that representation is "broadcast" and begins to influence cognition in particular ways (Smith, 2016). This would entail that there are no phenomenal experiences that are not consciously accessible (also see Baars et al., 2005).

Therefore we hold that the qualia/phenomenology associated with a represented emotional response only becomes present when that representation is selected for conscious access via the frontal-parietal mechanisms described above. We also stress the facts that 1) claims regarding the presence of phenomenal experience need to remain testable to advance scientific understanding, and that 2) because many types of learning/behavior can now demonstrably occur unconsciously in humans (Bargh and Morsella, 2008; Dehaene, 2014; Kihlstrom et al., 2000), only a limited set of behaviors can reliably be used to infer the presence of phenomenology/qualia in either human or non-human animals (including, but not limited to, verbal report behavior). We further wish to highlight that this approach can be extended to other animals. For instance, even though animals often cannot communicate their experiences directly the way humans can, one can find related evidence of conscious vs. unconscious processing in animals. For example, the neural signatures of global broadcasting (based on verbal reportability in humans) can also be detected in animals (Dehaene, 2014), and evidence of an animal's ability to hold information within working memory can also be gathered both behaviorally and neurophysiologically (Levy and Goldman-Rakic, 2000).

From the CN perspective, therefore, emotional reactions need not necessarily be consciously accessible. Importantly, unconscious emotion also need not be due to active suppression or inhibition (Levine, 2012), but can also be due to a failure to engage the next step in cognitive processing (e.g., as a result of not being selected for "broadcasting" by the gating mechanisms described above). This seems to be the best available explanation for several clinical phenomena (e.g., somatization in the context of affective agnosia; Lane et al., 2015b), and it also coheres nicely with the many well-studied unconscious effects on behavior now established within cognitive science, both within and outside of the emotional domain. Further, from the CN perspective it seems that considerations of phylogenetic continuity would argue in favor of a similar conclusion with regard to other mammals. That is, we see no reason to think that a non-human animal's emotional reactions are necessarily always conscious. This follows (1) from the fact that such reactions are not always conscious in humans, and (2) from the further lack of any explicit argument (to our knowledge) as to why humans and other animals ought to differ in this respect. For example, in a study on rat emotion, if the animal's peripheral physiology is altered and it adopts a reflexive defensive posture in response to some stimulus, then an emotional reaction may be inferred. But given that such changes can occur without awareness of an emotion in humans (that is, a human might deny any phenomenological experience of emotion in such contexts), why think this possibility is excluded in other animals?

Since non-human animals cannot provide verbal reports, this is difficult to test. However, other mammals appear to represent explicit goals (Sreenivasan et al., 2014), and they also appear to have the relevant gating mechanisms associated with attentional

[7] Although, some of these phenomena might also, strictly speaking, be caused by the outputs of unconscious appraisal mechanisms. They need not all result as an effect of unconsciously representing one's emotional reaction itself.

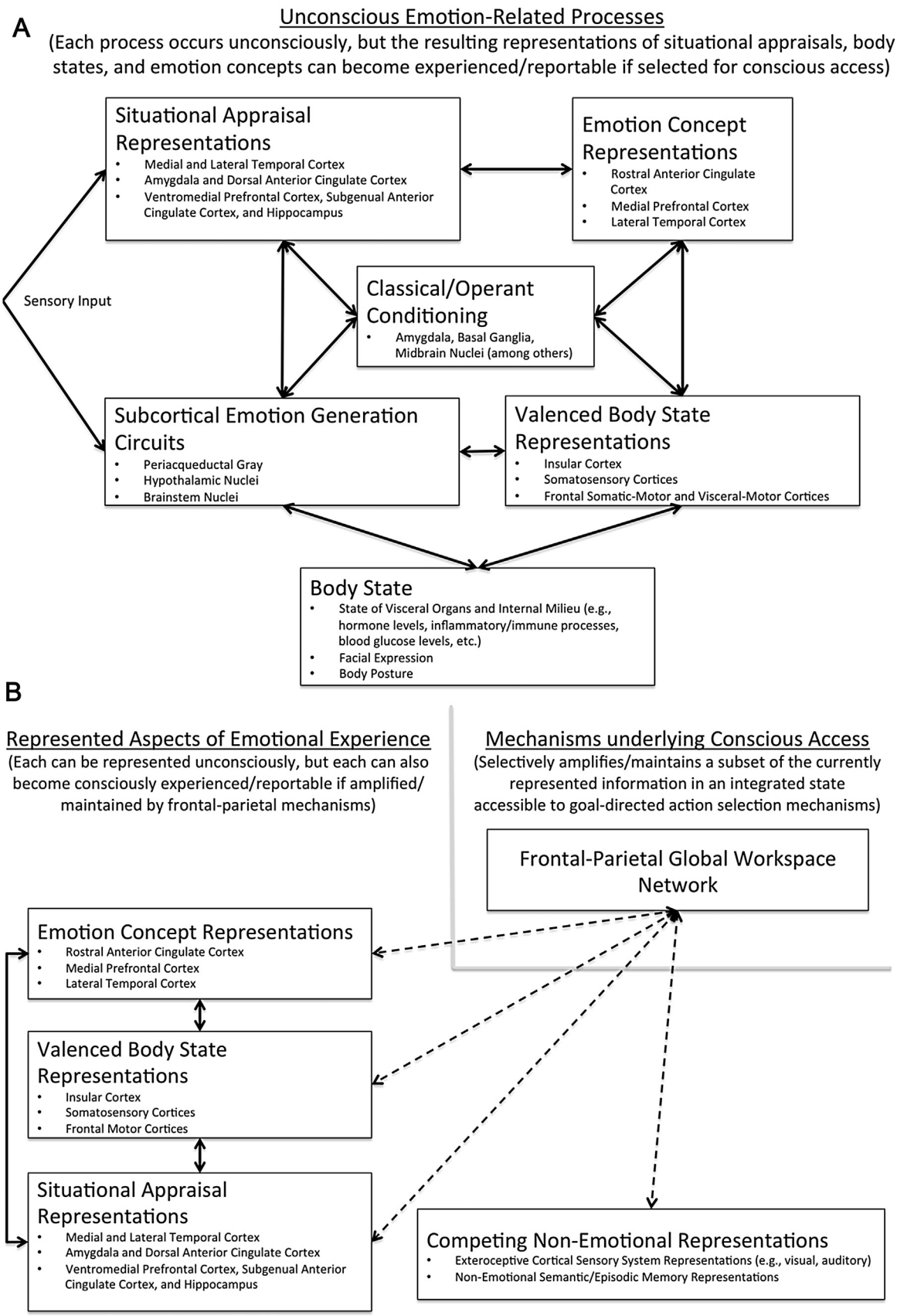

Fig. 1. (A) Illustrates the various emotion-related processes that can occur unconsciously according to the CN model (and examples of brain structures implicated in each process). (B) Illustrates the mechanism whereby representations generated by the processes in (A) can compete with other unconscious representations for global broadcasting. If an emotion-related representation (e.g., a valenced body state representation) is globally broadcast (via selective top-down amplification from the Frontal-Parietal Global Workspace Network), then that body state will become phenomenally experienced and able to be integrated with other consciously accessible information to guide goal-directed cognition and action selection. Crucially, on the CN model, an individual could gain conscious access to some emotion-related representations without gaining conscious access to others. For example, one could consciously experience a negatively valenced body state, but fail to gain conscious access

control and working memory maintenance/manipulation. Much of the cellular work on these gating mechanisms, associated with modulation of neural representations into specific oscillatory frequencies, has been performed in non-human animals (Fries, 2005; Roux and Uhlhaas, 2014; Womelsdorf and Fries, 2007). In fact, one recent neural model of consciousness partly inspired by this animal work (Prinz, 2012) has proposed that the gamma oscillation frequency may be identified with the minimal notion of "availability" to working memory associated with (an empirically testable) phenomenal consciousness, and that the theta oscillation frequency may be identified with working memory maintenance (and therefore reportable access consciousness). So it appears that cognitive models of access consciousness ought to be applicable to other animals, at least in many respects. If representations of one's own emotional state can be selectively made access conscious in humans, and the brains of other mammals also contain working memory systems with similar gating mechanisms, it seems that conscious and unconscious emotion ought to be possible in other mammals as well. Given sufficient phylogenetic continuity, we see this as an area of potentially great importance for further insights into the neural basis of emotional experience and emotion-related psychopathology.

From the CN perspective, subcortical emotion circuits (i.e., survival circuits; LeDoux, 2012) are best viewed as mechanisms for triggering various "automatic" (i.e. not consciously controlled) autonomic and behavioral reactions, as well as for triggering various modulatory influences over cognitive functions such as attention, memory, and decision-making. In the case of fear, for example, this might include automatic behavioral reactions such as facial expressions and defensive postures, increases in sympathetic tone, increased attention toward cues of threat, an increased tendency to recall threat-relevant information, and so forth. Such reactions clearly can be a part of the experience of an emotional reaction broadly construed, but, from the CN perspective, these aspects might also be distinguished from emotional phenomenology itself. Emotional phenomenology likely involves at least three further elements. First, it appears to involve activating representations of the bodily reaction triggered by such subcortical mechanisms. This will involve (among others) the insular, somatosensory, and anterior cingulate cortices (Adolphs et al., 2000; Barrett and Simmons, 2015; Craig, 2009; Gu et al., 2013), and should proceed similarly to processing within other cortical sensory systems. Second, it will involve the activation of emotion concept representations, such that emotional meaning is assigned to the aforementioned bodily reactions. This likely involves neural representations distributed across the rostral anterior cingulate region (rACC), adjacent medial prefrontal cortex (MPFC), and also the lateral anterior temporal lobe (LATL) (Kalisch et al., 2006; Peelen et al., 2010), as well as other regions of the "default mode network" (which is implicated in the process of conceptualization as a whole; Barrett and Satpute, 2013). Third, the representations within these various regions will need to be made consciously accessible, via selective broadcasting to the frontal-parietal networks described above. This selective broadcasting likely involves bi-directional interactions with regions of the DMPFC associated with affective working memory maintenance (Waugh et al., 2014), but also plausibly involves similar interactions with lateral frontal-parietal networks (Barrett and Satpute, 2013; Xin and Lei, 2015). Therefore, while subcortical emotion circuits are important for generating these broad multifaceted emotional reactions, from the CN perspective, a phenomenological emotional experience involves considerable cortical contributions associated with representation of bodily sensations and their conceptual meaning, as well as cortical mechanisms associated with affective working memory and selective broadcasting.

While the CN perspective holds that emotional reactions *can* be unconscious, it is also important to make clear that there are reasons to think that, at least in healthy individuals, certain types of emotional responses will typically be consciously experienced the majority of the time. The reason is that certain emotional responses – imperative homeostatic emotions in particular – involve the generation of intense, negatively valenced sensations and drives that effectively attract one's attention (Denton et al., 2009). Thus, the representations of such emotional responses may have an inherent advantage in the competition for conscious access. As such, while it is possible that representations of these types of emotional responses will not be selected for global broadcasting, this may be rare in practice and may occur mainly in cases involving intense concentration on a secondary task or in cases involving neurological or psychiatric pathology. In contrast, other types of emotional responses (e.g., low arousal, positive emotions) plausibly occur in the absence of awareness much more often.

3.4. Language, concepts, and thought

From the CN perspective, a further, fairly complex issue of considerable importance involves uniquely human linguistic and conceptual capacities, and the way these capacities relate to emotional experience. Concepts are understood to be the representational building blocks of thought, and considerable recent evidence suggests that concepts are often represented within sensory-motor systems in a non-linguistic format (Kiefer and Barsalou, 2013; Simmons et al., 2008). In fact, one account identifies concepts with perceptual and motor representations (e.g., visual, auditory, linguistic etc.) that are capable of being maintained/manipulated within working memory (Prinz, 2002). Recent "hub-and-spoke" models of concept representation within the brain (Pobric et al., 2010) also provide evidence that there may be abstract semantic "hub" representations of concepts within the LATL, in addition to the sensory and motor "spoke" representations described above. Based on these models, the lack of linguistic capacity in animals does not appear to preclude their ability to think or possess concepts. Yet, language in humans plausibly facilitates the formation of complex, abstract concepts that other mammals are likely incapable of forming. It is unclear whether emotion concepts (such as those expressed by terms like "sad" and "scared") could be innately possessed by animals, or if not, whether non-human animals would be capable of learning such concepts in the absence of language. It is also unclear whether the possession of emotion concepts is a necessary condition for the differentiated emotional experience of feelings (as opposed to undifferentiated valenced arousal, for example). If emotion concept representation was necessary for emotional experience (i.e., if it partly constituted emotional experience), for example, and if non-human animals did not possess emotion concepts, then this might suggest that a non-human animals' experience of an emotion was exhausted by bodily phenomenology.

The CN view, therefore, makes no firm claims with regard to the number/types emotion concepts that animals possess. It also makes no firm claims regarding whether or not such concepts are required for emotional experience. Minimally, it appears plausible to us to assert that emotional experience can be decomposed into

to its associated emotion concept representation (e.g., they wouldn't consciously recognize they were afraid) or to its associated appraisal (e.g., they wouldn't consciously know a potential threat had been detected). Solid lines indicate two-way interactions that do not depend on consciousness. Dotted lines indicate two-way interactions – between representations and the Global Workspace Network – that are only effective if a representation is selected for conscious access (i.e., global broadcasting).

multiple percept-level and concept-level representational building blocks, and that some of these building blocks might be preserved in the absence of others. Thus, even if animals lacked emotion concepts, one could claim they still retain some elements of emotional experience, even if they lack others. These are open empirical/philosophical issues. However, we do find it plausible that human linguistic capacities likely facilitate the formation of much more complex and nuanced emotion concepts than other animals could possess (some of which may be of a culturally specific nature; e.g., several tribal cultures/languages do not fully distinguish anger from sadness; see Russell, 1991).[8] Learning such nuanced and differentiated emotion concepts through language, at the very least, can allow humans to attend to, discriminate, and differentially respond to patterns of emotional experience that they otherwise would not. Current evidence in vision research, for example, suggests that linguistic category (and presumably conceptual category) differences facilitate processing speed in color discrimination (Winawer et al., 2007), but it does not show that such conceptual differences result in different color experiences. Thus, the CN view simply suggests that language very plausibly improves the adaptive use of emotional experience within downstream cognitive systems (e.g., increases in discrimination etc.), and that it could potentially alter emotional experience as well. We see no firm reason to conclude that affective experience is absent in non-human animals, although it may be less differentiated in various ways.

While it is unclear whether emotion language and emotion concepts are necessary for emotional experience, the possession/activation of emotion concepts (like "sad" or "angry") within the cortical regions discussed above could plausibly alter the phenomenology of an emotional response in particular ways. For example, activation of emotion concept representations might alter the bodily aspects of emotional phenomenology indirectly via top-down feedback mechanisms that subsequently influence bodily reactions or the way they are perceptually represented (similar to top-down pattern completion mechanisms in visual perception, for example; e.g., McClelland and Rumelhart, 1981). Recent work within the theoretical neurocomputational framework known as "predictive coding," for example, also strongly suggests that this type of indirect top-down influence of emotion concepts on bodily phenomenology should be present (Hohwy, 2014; Seth, 2013). At the very least, the possession of such concepts, and the ability to activate such concepts appropriately in response to experiencing the cognitive/bodily reactions triggered by subcortical emotion circuitry, appears highly significant to the way one understands, deliberates, and ultimately voluntarily responds to such emotional reactions. Therefore, while the CN perspective fully acknowledges the relevance of innate subcortical emotion circuitry in emotion generation, when considering the conscious perception and recognition of one's own emotional reactions (and the way they are subsequently used in goal-directed cognition), individual and cultural learning processes appear to be of considerable importance. (See Section 4 for the AN view's critique of this perspective.)

4. Critique of the CN perspective (by JP & MS)

The goal of AN is clearly more delimited than that of CN, since the former focuses on clarifying the sub-neocortical emotional systems, and the affects they generate, as opposed to their cognitive ramifications, while the CN approach seeks to conceptualize the whole, although they focus more heavily on the upper than the lower parts (as highlighted in Fig. 1). For instance we have no problems with the many cognitive aspects that the human CN perspective seeks to illuminate (e.g., we do find it plausible that "human linguistic capacities likely facilitate the formation of much more complex and nuanced emotion concepts than other animals could possess"). The cross-species AN approach is focused on illuminating the nature of raw (cognitively unprocessed) affective experience. Of course, both AN and CN are interested in basic learning mechanisms, and both can contribute much at that level, and as one goes "higher", emotional concepts surely must get more complex. It goes without saying that human emotional life is both enriched and complexified by higher mental processes, such as thoughts, introspective states (so-called "awareness" of feelings as opposed to sentient feelings themselves) and explicit decision making processes, which are comparatively difficult to study in animals. Without verbal self-reports, some cognitively oriented investigators of animal emotions believe the whole issue of experienced feelings in animals is a non-starter (e.g., LeDoux, 2012; Rolls, 2014). Obviously human CN is better situated than animal AN to probe the higher cortico-cognitive processes that "gate" the affective processes that are "globally broadcast" from the upper brainstem and associated circuits. On the other hand, the direct study of emotional affective states (not to mention homeostatic and sensory affects) in human brains remains fairly primitive, although the best correlative work, such as that of Derek Denton's group (2006, 2009) and Antonio Damasio's group (Damasio, 2010; Damasio et al., 2000), is concordant with DBS and neurochemical constitutive work in animals.

The dilemma of psychological-state "reportability" has hindered the study of emotional feelings in animals ever since the inception of a scientific psychology, from Wundt onward through the 20th century, with only a partial decline in the last decades, largely because of the emergence of a cross-species affective neuroscience (Panksepp, 1981, 1982, 1998a). During that same time period, modern brain imaging opened up the possibility of clarifying human emotional-feeling, at least the brain correlates as well as diverse cognitive reflections and decision-making processes that raw affective states guide and promote. However, with respect to the neural understanding of the *constitution* of human emotional feeling, we must realize that human brain imaging measures are strictly correlative. It is scientifically difficult to relate correlates to causes, without direct interventions in the relevant brain systems, as with brain stimulations, or circuit disruptions, whether electrically or neurochemically. We spent considerable time trying to get direct electrophysiological measures of human affective states from cortical EEG indices, but only found that the theta power increases were most indicative (correlatively) of emotional responsivity (Bekkedal et al., 2011).

Animal work permits causal studies more readily (see Panksepp, 2015a,b for thorough discussions). AN is premised on the idea that the most important facet of brain emotionality that is especially relevant for medical disciplines, such as psychiatry, might be the neural constitution of primal emotional affects, which is more scientifically tractable in animal models than human studies (as was the case for the genetics/molecular biology revolution). This is based on the recognition of deep evolutionary homologies within the affective functions of subcortical systems of all mammals. Although animals cannot give us verbal self-reports of such states, they can behaviorally "inform" us whether various evoked brains states are affectively neutral or rewarding or punishing—the latter being our gold standard for monitoring affective shifts explicitly in non-speaking animals (corresponding, if evolutionarily conserved, to homologous emotional feelings in humans). If so, such knowledge provides a clear road to development of new psychiatric

[8] A thorough discussion of candidate culturally specific emotion concepts, and how they could be learned as a result of culture-specific emotional terminology, is beyond the scope of the present article. For discussion of multiple examples of cultural differences in emotion concepts, see Mesquita and Frijda (1992) and Russell (1991).

interventions (Panksepp et al., 2014; Panksepp, 2015a, 2016). Thus the most important empirical issue from our cross-species AN perspective is to have better understandings of how rewarding and punishing emotional states are neurally engendered, especially in animal models where the relevant neural details can be illuminated. Clearly, animal models are woefully deficient in studying associated cognitive shifts, in which human research excels, as highlighted by RS & RDL.

The neural constitution of raw affective feelings in the brain has long remained the most difficult problem faced by CN (since it is part of the so-called "hard problem" of consciousness studies). It is also true that the diverse human cognitive elaboration and declarative "awareness" of emotions, that are typically the focus of CN (thoughts and decision-making, that are often promoted by affective shifts), present remarkably difficult problems for a cross-species AN (but see Mendl et al., 2010; Rygula et al., 2015, 2012; Steiner and Redish, 2014 for some recent advances in the area). Our position is that the neural constitution of primal affects may not be solved in humans until we know how affects are constituted in our fellow animals. Thus, for AN, a key goal is to decipher the primary nature (the neural constitution) of the primal emotional feelings—disturbances of which may engender major affective disorders (e.g., post-traumatic anxiety, depression, panic, manic and addictive disorders). If we do share homologous sub-neocortical emotional affects with other mammals, as the data so far strongly indicates, we can make substantive progress by deploying animal models of disordered affective states to understand the human equivalents, yielding new concepts for therapeutics (for recent overviews, see Panksepp, 2016, 2015a).

As RS & RDL emphasize, affective arousals also drive the vast human cognitive apparatus, which can in turn sustain affective arousal by ruminations while reducing them by higher order emotion regulations. However, to the best of our current knowledge, it is impossible for the cortico-cognitive apparatus alone to *constitute* the emotional-affective valences of raw (cognitively unprocessed, subcortically generated) emotional feelings, and human CN tools are not optimal for doing causal brain research. But new technologies (such as transcranial magnetic stimulation; TMS) may be able to counter our skepticism, and RS & RDL do entertain various fascinating perspectives on how the neocortex contributes to cognitive shifts and decision-making promoted by raw affective experiences. As RS & RDL summarize, this represents an enormous area of inquiry by many investigators, with a new generation of young cognitively oriented affective neuroscientists doing human research leading the charge in the modern era largely because of linguistic access to affective shifts and modern functional brain-imaging, which is at times productively guided by earlier animal studies (e.g., Eisenberger, 2010; Kennedy et al., 2006; Mobbs et al., 2007; Zubieta et al., 2003) but often travelling different paths (e.g., Lindquist et al., 2012). Such efforts are proceeding robustly at both purely psychological and cognitive neuroscience levels. These are major contributions to our fully integrated understanding of emotional/affective decision-making and many other cognitive processes discussed by RS & RDL, which simply can't be studied as well in non-speaking animals. Regrettably, the vast majority of such important cognitively oriented research adds little neuroscientific understanding of how primal affective states are actually constituted by the subcortical neuroanatomies, neurochemistries and neurophysiologies of mammalian brains. That vast territory of nature has been largely left to a cross-species AN, supplemented by ever increasing efforts from other human neurosciences, such as neuropsychoanalysis (for recent compendiums, see Fotopoulou et al., 2012; Solms, 2015).

We are surprised how few cognitive neuroscientists are eager to integrate primary-process affective findings into their repertoire of knowledge about higher mental functions – e.g., how primal emotional affective systems influence thoughts and cognitive judgments, not to mention attention and perception, and even emerging disciplines like neuroeconomics (for a recent readable overview, see Johnston and Olson, 2015). Indeed, one of Panksepp's former post-docs, Brian Knutson (Stanford) confided that the reason he did not use the term "SEEKING" (exploration/enthusiasm) system as opposed to "the brain reward system" in his neuroeconomics and related works (e.g., Haber and Knutson, 2010), was simply because then he would not get his papers published. In short, the ghost of behaviorism still haunts many psychological laboratories. Scientific conservatism is understandable (since we always rely on the "weight of evidence"), but not if it closes doors to data-based, reasonable possibilities (e.g., that rewarding and punishing DBS that evokes emotional behaviors, also evokes corresponding feelings), especially when those understandings provide new approaches for treating human emotional problems (Panksepp et al., 2014; Panksepp, 2015a, 2016). Clearly, absolute assertions (e.g., "We will never know what other animals feel", LeDoux, 2012), which remain all too common biases in behavioristic neuroscience, do not contribute to reasoned, prediction-based, scientific discourse about affective feelings in animals.

A critical scientific issue is whether understanding of animal affective brain functions can illuminate homologous emotional, homeostatic and sensory affective processes in humans. There is abundant evidence that it can. Here is an example: One of AN's discoveries was the fact that brain opioids are remarkably effective in reducing the psychological pain of separation-distress arising from brain networks that were identified through animal work with DBS (Herman and Panksepp, 1981; Panksepp et al., 1980, 1978). If these systems in the human brain are homologous to those in dogs and guinea pigs (and even chickens), traumatized humans should be somewhat more susceptible to becoming addicted to opioids than those who do not have sensitized FEAR and PANIC (separation-distress) systems (i.e., highlighting which imbalanced brain systems are being self-medicated). The same applies to clinical depression: To the extent that this common disorder is due to overactivity of the separation-distress (psychic-pain) networks, it should respond well to the relatively safe opioids. That is, relatively "safe opioids" such as buprenorphine and tramadol may be quite effective in treatment-resistant depressions, a prediction that has been confirmed (e.g., Panksepp and Yovell, 2014; Yovell et al., 2016). Also, the neurochemistries of positive social affects, as generated normally by PLAY interactions (Burgdorf et al., 2007), should diminish the psychological pain of depression (Burgdorf et al., 2016, 2011; Panksepp, 2015a; Panksepp et al., 2014). Likewise, in treatment resistant depression, perhaps an optimal target for DBS therapy would be the enthusiasm/interest generating SEEKING urge (Coenen et al., 2012; Panksepp and Yovell, 2014), another predictions that has been confirmed (Schlaepfer et al., 2013). Those antidepressant effects were not accompanied by elevated pleasure, but the desire to engage the world again.

When we discovered the power of opioids to quell the psychological pain of separation (Panksepp et al., 1980, 1978), mediated by the PANIC system (mapped with DBS in both guinea pigs and young chicks; Panksepp et al., 1988), it was at a time when there was little discussion of how extensively human opioid addiction may arise from self-medication practices of individuals who learn that they can regulate their persistent feelings of loneliness-related distress (often arising from lack of mental health sustaining social support networks). We sought to bring such issues to the forefront of cultural discussions, but editors/reviewers requested that such affective "speculations" be expunged from the earliest submissions of our empirical work. And to this day, especially now that we are in another opiate-addiction epidemic (e.g., see *Time* magazine July 7, 2015: http://time.com/3946904/heroin-epidemic/), such conversations are still all too commonly avoided due to ongoing "wars

on drugs", without any adequate recognition that many addicts are self-medicating their depression-promoting psychological pain. Meanwhile animal studies have clarified the affective underpinnings of opioid and psychostimulant addictions (Koob and Volkow, 2010; Panksepp et al., 2004) but little of that has become standard knowledge, partly because of artificial separations between cognitive and affective approaches to understanding the mind (with animal investigators often not participating in affective discussion because of "never mind" behavioristic biases, and the difficulty of modeling human cognitive abilities in animals). A better integration of CN (top-down) and AN (bottom-up) approaches may contribute much to solving such historical/conceptual problems.

Indeed, with regard to the issue of "psychological pain" it may be that the nonspecific therapeutic effects of psychotherapy are due to the warm and supportive human qualities of clinicians, that promote opioid release in patients'/clients' brains. In other words, feelings of positive social-support should be very effective in reducing opiate addictions in humans, since such positive social interactions increase release of opioids within animal (Panksepp and Bishop, 1981) and human brains (Dunbar, 2012; Zubieta et al., 2003), especially in brain regions known to be rich in separation-distress/PANIC circuitry (Herman and Panksepp, 1981; Panksepp et al., 1988). Indeed, positive social companionship can dramatically reduce drug addictions in rats (Alexander and Hadaway, 1982), and therefore potentially in humans as well.

We use this simple example to bring home the general principle that, to the best of our knowledge, all mammals *do* share homologous emotional feeling/behavior (but fewer cognitive) systems, which should permit certain behavioral and psychophysiological measures to be used as indices of subjective arousal, especially if those states are demonstrably rewarding or punishing (e.g., as evoked with DBS). Evidence for non-existence (in this case, of subjective feeling) is always harder to find than evidence for existence. Thus we envision that the human cognitive neuroscience of emotion could be greatly enriched by seeking its primal affective foundations in cross-species investigations of subcortical emotion circuits—levels of brain-mind organization that are not readily accessible in human research. Of course many clinicians subscribe to such views, but the academic field of CN often does not. There are many other examples that could be used to illustrate this point (see Panksepp and Biven, 2012; Panksepp, 1998a; Solms and Turnbull, 2002; Solms, 2015). It is clear that the issue of affect regulation is one of the biggest challenges in psychiatry, and cross-species affective neuroscience research can facilitate the essential bottom-up neurochemical view, while top-down cognitive neuroscience research is essential for having a clearer vision of how psychotherapeutically facilitated changes in the higher mental processes of humans impact the various patterned expressions and regulation of basic affective processes.

Thus we completely agree with our collaborators on this paper that it is understandable that human research can hardly make "firm claims with regard to the number/types of emotion concepts that animals possess" (and we might note how many "primal emotions humans possess") since it has no direct manipulative access to the relevant (generally slowly firing) subcortical circuits (but see Panksepp, 1985), where synaptically released neurochemistries are more important than the rates of neuronal activity (that fMRI studies commonly highlight). In general, subcortical neurons tend to fire at much lower rates than cortical ones (a largely unrecognized bias in human brain imaging). It is also likely "that human linguistic capacities likely facilitate the formation of much more complex and nuanced emotion concepts than other animals could possess." These dilemmas suggest that an evidence-based *synthesis* of views is needed, especially in subcortical regions, wherever that is possible (e.g., Dunbar, 2012). Thus, we argue that the animal research will be most valuable for clarifying (i) the raw affective foundations of human minds and also (ii) the basic learning and memory mechanisms that distribute such mental powers into the complexities of human cognitive activities, which are mostly learned. The first is well on its way, as well as the second, although new neurochemical "Laws of Affect" (Panksepp, 2011b) may be needed to supplement the excellent neurobehaviorist work on learning and memory (see LeDoux, 2012; Rolls, 2013, 2014; including commentaries).

As RS and RDL correctly highlight, the psychotherapeutic and thought-related issues are more clearly illuminated by human CN than animal AN research (Lane et al., 2015a). However, neuropsychoanalytic approaches deploy both (Fotopoulou et al., 2012; Solms, 2015). In this context, it is noteworthy that the clinically important phenomena of memory reconsolidation was first discovered in animals (Lewis et al., 1968; Misanin et al., 1968), and future work in animals will continue to have many implications for human therapeutics (Lane et al., 2015a). The big question now is whether AN and CN approaches, with quite different intellectual histories, can be productively synthesized. This said, we would simply suggest that the existence of cortex (i.e., pallium) in all vertebrates, which may participate in emotional and other affective process regulations from birth onward, provides one point of synthesis between AN and CN approaches to understanding the mind (regrettably, functional data on the affective-cognitive developmental processes in cortical areas of infants remains a poorly studied area of potential fruitful integration).

In sum, via decortication studies and diverse subcortical DBS valence-studies it is reasonable to conclude that various distinct emotional proclivities were programmed into subcortical regions of the brain by evolution, and their mediation of affective states is supported by the robust fact that DBS of such emotion evoking circuits, and their main neurochemistries, are "rewarding" and "punishing" in all animals so far studied, humans included (Panksepp, 2005, 1998a, 1981). Very few such affective sites have been found in neocortical regions (we assume they would exist, if the neocortex is essential for generating the feelings of emotional arousals). Likewise, damage to neocortical sites generally increases rather than decreases (let alone abolishes) felt affectivity. As already noted, how far back valenced "states of mind" go in neural evolution remains an open issue (Huber et al., 2011; Feinberg and Mallatt, 2016; and for spirited debates, see the new open-access e-journal: *Animal Sentience,* readily accessible on the web).

In this spirit, our direct questions regarding the CN approach are as follows:

1) AN is premised on an evolutionary view of caudo-rostral and medio-lateral brain development, leading to evolutionary levels of nested hierarchical (highly interactive) controls (Fig. 2): with (i) earlier *primary*-processes—including the evolutionary solutions of instinctual-unconditioned emotional response systems – guiding more recent brain functional-specializations, such as (ii) *secondary*-level learning and memory levels of control in basal ganglia and archi/paleo cortices, and (iii) more recent mammalian neocortical expansions, supporting abundant *tertiary*-level cognitive-process that arise from the most rostral neocortical expansions (resembling empty RAM in digital computers), which provides computational space for the learning/programming of diverse higher-order (not evolutionarily programmed, but developmentally learned) cognitive-affective strategies (for fuller descriptions see Panksepp, 2015b, 2011a). This is a didactic simplification (as much of psychological science is), but we think CN needs to be explicit about its neuro-evolutionary perspective on primal affects, especially the actual subcortical mechanisms of raw emotional feelings. (The sensory and homeostatic ones, such as *surprise* and *hunger*, important as they are for psychology, are less relevant for psychiatry.) How does CN envision the evolutionary construction of the brain and

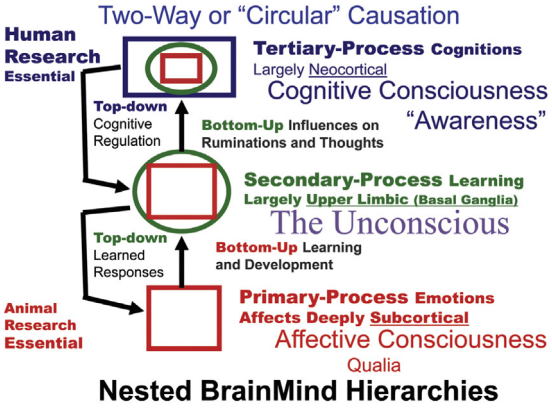

Fig. 2. (adapted from Northoff et al., 2011). A conceptual overview of nested-hierarchies of emotional-affective control within the brain. A hierarchical bottom-up and top-down (circular) causal organization is proposed to operate in every mature primal emotional system of the brain, with the lower primary-processes having emerged earlier in brain-mind evolution (as well as ontogenetic development)–with *primary* evolved affective *emotional* valences (as well as *homeostatic* and *sensory* processes) being depicted as squares (red), *secondary*-processes of learning and memory as circles (green), and higher-order *tertiary* cognitive reflective-planning processes, by rectangles (blue). This schematic also highlights the hypothesis that in order for higher MindBrain "awareness" (cortical) functions to mature and function (via bottom-up control), they still have to be guided by and integrated with the lower BrainMind functions, which are the primary foundations of consciousness (for extensive summary, see Watt and Pincus, 2004); namely primary-process affects are essential for tertiary-processes to continue to operate normally. In short, this color-coded hierarchical schematic seeks to convey the manner in which emotional complexities reflect nested-hierarchies that are integrating lower brain functions into higher brain functions–a developmental conditioning/molding process that eventually allows top-down regulatory control (e.g., thoughts controlling feelings). Raw affects, as monitored by valence (rewarding and punishing properties of DBS applied to relevant subcortical systems), are already a property of subcortical emotional dynamics, which survive radical neo-decortication. Thus primal *emotional* consciousness (a variant of *affective* sentience) emerges largely from deep sub-neocortical regions of the brain, while aspects of cognitive consciousness (reflective "awareness" and "decision making") are developmentally programmed higher brain functions. These higher brain functions are programmed by intermediate brain structures commonly called the "basal ganglia" (amygdala, bed-nucleus of stria terminalis, caudate-putamen, septal area) as well as hippocampus—relatively subconscious (largely unexperienced), secondary-process mechanisms of learning and memory formation—whose functions are critically dependent on the environmentally-linked "tides" of primary-process affective, survival-value indicators (i.e., via currently poorly understood neural "Laws of Affect"). Each level of control deserves distinct nomenclatures; thus, for the all important SEEKING Enthusiasm/Expectancy System, a good secondary-process label might be "Wanting," while "reward-prediction error" may be a more debatable-formalistic (non-psychological) tertiary-process terminology to talk about the neural formation of enthusiastic or threatening cognitively-experienced *expectations*. Of course all these systems are relatively nonspecifically controlled by general-purpose "arousal" and "power/surgency" systems. These are constituted, in part, from lower and upper brainstem-based systems, including local as well as ascending acetylcholine, glutamate, norepinephrine and serotonin systems modulating diverse higher neuro/psycho-dynamic functions. For a more cognitively and conceptually (but not affectively) resolved view of such brain hierarchies, see Smith and Lane (2015). In affective neuroscience's vision of brain organization, primal experienced affects are constituted by sub-neocortical systems, while cognitive neuroscience approaches instead propose that cingulate, frontal, and insular cortical processes translate intrinsically unconscious neural activities into affective experiences. Affective neuroscience argues that the DBS evidence for subcortical rewarding (pleasurable) and punishing (aversive) states, even in neo-decorticated animals, demonstrates the sub-neocortical constitution of most major affective experiences, while neocortical processes regulate and parse sub-cortically generated affects much more than formally *constituting* affective experiences. It will be intriguing to determine how lesions of the aforementioned older cortical regions will influence reward and punishment thresholds evoked by various subcortical DBS challenges. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

mind without an explicit "nested hierarchy" view (e.g., see also Feinberg, 2011; Northoff et al., 2011)?

2) In this context, it is again important to consider that much of the massive neocortical expansions since human divergence from other great apes was substantially controlled by a single gene variant, *ARHGAP11 B* (see Florio et al., 2015; with, 55 other genes "preferentially expressed in human apical and basal radial glia that lack mouse orthologs"). We think such findings provide little leeway for robust and specific *genetic* control of various higher neocortical primary sensory and affective functions, except perhaps in the more ancient cingulate, frontal, insular and orbitofrontal cortical specializations, whose functions may still be rather directly controlled (guided) by the more basic subcortical affective processes. This raises the question: how can CN help decode the neuro-anatomical/-physiological and neurochemical foundational mechanisms of human primal emotional-affective states (that we infer, with predictions for humans, from the explicit rewarding and punishing properties of DBS applied to subcortical circuits that evoke distinct emotional action patterns along with rewarding and punishing effects)? We believe CN needs *explicit* AN-type views of evolved hierarchical brain-mind controls to guide constitutive/causal cross-species understanding of the diverse neurally homologous subcortical "survival values" (i.e., valenced affects) encoding circuits of mammalian brains. We propose that CN needs to be clearer about such neuro-evolutionary perspectives on the constitution of primal emotional affects. Indeed, subcortical DBS of the human brain yields more robust affective changes (see Panksepp, 1985) than any form of neo-cortical stimulation has so far achieved.
3) In our estimation, elaboration of affective states in cortical brain regions, important as they may be for the construction of higher order emotional concepts, remain critically dependent on more ancient subcortical controls. If so, how can CN (without an understanding of subcortically-mediated primal affects) develop new evidence-based neurobiological treatments for the diverse affective disorders, where molecular refinements to treatments discovered by serendipity, rather than our explicit understanding of how brain neurochemistries generate emotional affective states, have so far led the way?
4) How does CN explicitly explain the varieties of emotional responses, as well as rewarding and punishing states, evoked with DBS applied to deep subcortical brain sites in decorticated animals (Huston and Borbely, 1973, 1974; Valenstein, 1966) and the many findings of seemingly homologous affective responses in humans when stimulated in these same brain regions (Panksepp, 1985)? How can such findings be reconciled with the CN view that emotional feelings are largely generated cortically? Can CN envision the evolutionary neural construction of affective states without an explicit focus on primal subcortical emotional states evoked by subcortical DBS? This said, we have no doubt that many aspects of affectively guided behavioral and cognitive choices require cortical participation.
5) Finally, we would ask our colleagues to address the evidence from hydranencephalic children, which seems to support the AN argument. These children have been characterized as "conscious" on the basis of a reported ability to exhibit contextually relevant and appropriate responses of pleasure or excitement that evince a coherent interaction between environment, motivational–emotional mechanisms and bodily actions (for full discussion, see Merker, 2007). In line with this human neurological observation, the survival of primary process emotions is highlighted by the survival of all the basic emotional systems after radical neo-decortication of rats; these animals still exhibit all the primal emotional patterns (Kolb and Tees, 1990; and for our work on PLAY in decorticate animals see Panksepp et al.,

1994). Similar considerations apply to less radical lesions affecting cortical areas which are specifically associated with affective "awareness": e.g. prefrontal and insular regions (e.g. Damasio et al., 2013); why do such patients not display – and report – the loss of affective consciousness that CN views should predict? Also AN does not discuss "awareness" in animals, since it implies knowledge that one is experiencing. We simply focus on affective sentience—the primal experiencing of various subcortical valenced states of the brain. (See Section 7 for the CN view's response to this critique.)

5. Critique of the AN perspective (by RS and RDL)

From the CN perspective, we see great promise in the cross-species methods advocated by the AN perspective. The types of experimental manipulations in animals described above appear capable of providing novel and important insights into the nature of both the subcortical and cortical systems within the brain that have been linked to affective functions. Moreover, the overarching goal of identifying the neural basis of subjective feelings states is highly laudable and potentially foundational for basic cognitive and affective neuroscience and their translational applications to clinical medicine and psychiatry. Yet, we also see a number of important flaws in the theoretical framework currently advocated by the AN perspective. We will now outline some of these drawbacks, and attempt to explain where we believe the major problems exist. However, as certain aspects of the AN perspective, such as its assumptions regarding brain evolution, have been critiqued previously (Barrett et al., 2007a), we will focus on contributions to the literature that are novel to our knowledge. Throughout our critique, we will highlight direct questions for the AN perspective (these questions are then summarized at the end of the section).

Above, JP&MS state that raw (unconditioned) affects "emerge" from subcortical brain regions and not cortical ones, and that they use the word "affect" to denote "raw subjective feelings" as opposed to their "cognitive elaborations." We believe that this type of pre-theoretic terminology is vague/imprecise, and as such can lead to considerable confusion. For example, does the idea that emotions "emerge" subcortically simply mean that emotional reactions are generated by these structures? Or does it also mean that activity in these structures *alone* is sufficient for consciously experiencing those reactions?

We would agree that subcortical structures play a central role in generating an emotional reaction. From the CN perspective, an "emotional reaction" includes the generation of both a coordinated bodily/behavioral response (i.e., autonomic, neuroendocrine, musculoskeletal) and a coordinated cognitive response (i.e., biases in attention, memory, and decision-making), and various subcortical structures appear well-positioned to proximally initiate both of these types of coordinated changes. However, we have argued in detail elsewhere that the generation of such a reaction is not sufficient for becoming consciously aware of it (Smith and Lane, 2015). Becoming conscious of such a reaction, we argue, further requires that its various aspects are 1) detected by afferent processing systems (e.g., interoceptive/somatosensory systems), 2) appropriately represented at both the percept- and concept-level, and 3) that these representations out-compete other currently represented pieces of information in the competition for conscious access (based on factors such as attentional selection, saliency, goal relevance, afferent signal strength, etc.). For example, just as a demanding secondary task can cause "inattentional blindness" for salient visual stimuli (Simons and Chabris, 1999), similar circumstances involving high cognitive load might also cause one to momentarily fail to become conscious of one's own emotional reaction. Thus, we disagree that subcortical activation alone will be sufficient for causing a conscious feeling. Just as a meaningful object can be detected by the visual system, and its colors, shape, texture, and conceptual interpretation can be represented, all without that shape being consciously experienced or recognized (Cacciamani et al., 2014; Dehaene, 2014; Dehaene et al., 2006; Sanguinetti et al., 2014), we suggest that emotional reactions can also be initiated, detected, and represented without being selected for conscious access (and hence without generating a reportable/verifiable subjective feeling). While the theoretical models appealed to by CN make it clear exactly when and why an event – whether cognitive or affective—will be consciously experienced (i.e., it must be represented and successfully compete for conscious access), it is not clear from the AN perspective why some cognitive processes can be unconscious but some affective processes can not.

A related terminological question we have is: what do the terms "raw subjective feeling" and "cognitive elaborations" mean? And how can a raw subjective feeling be empirically verified in humans? The reason these questions are important is that the presence of any particular conscious experience is most uncontroversially confirmed in humans, via some type of *intentional* or *goal-directed* "reporting" behavior. This could include a spoken or written verbal report, or it could also include gesturing or drawing a picture of what one consciously sees (for a non-verbal, drawing-type self-report measure of one's own bodily emotional feelings, see Nummenmaa et al., 2014). Crucially, however, many other *unintentional* behaviors can be affected by stimuli, even in the absence of such reports. For example, conscious visual processing does not appear necessary for patients with "blindsight" to avoid running into obstacles while walking, or to orient their hands to various objects (Cowey, 2010; Weiskrantz, 2009). Such patients deny experiencing anything visually, and yet their behavior still indicates that visual information is detected, represented, and used appropriately. A very large number of studies (reviewed in Dehaene, 2014) now confirm that this can also occur in healthy individuals, and in a wide range of perceptual and cognitive domains.

Further, there is now a very large literature on implicit learning and its neural basis (reviewed in Reber, 2013), which demonstrates that 1) behavioral performance can improve – in the absence of awareness – following repetition and positive/negative feedback, and that 2) such learning processes occur within regions associated with task performance (e.g., basal ganglia) and do not depend on neural systems associated with consciousness or declarative memory. Further, several animal studies have shown that both conditioned fear and conditioned taste aversion can be acquired during general anesthesia (Bermudez-Rattoni et al., 1988; Burešová and Bureš, 1977; Millner and Palfai, 1975; Pang et al., 1996; Roll and Smith, 1972; Rozin and Ree, 1972), when the animal could not be consciously perceiving the stimuli or consciously feeling the unpleasant responses that are learned from. Importantly, the behavioral increases/decreases that AN uses to infer conscious feelings in animals (e.g., their "Law of Affect") appear very similar to the implicit learning processes just described. Thus, it seems that these types of learning effects can occur unconsciously, and that the resulting behavior changes need not be seen as a reliable indicator of the presence of a conscious feeling (in animals or humans).

With regard to the AN perspective then, it is unclear how one can confirm/disconfirm the presence of a raw subjective feeling. Is the absence of verbal/behavioral reports sufficient to disconfirm a raw subjective feeling in humans? If the answer is no, then the presence of such feelings may fail to be empirically testable/falsifiable at all. This is because other types of behavioral/learning effects can occur without reportable awareness, and because the reportable/unreportable contrast represents the primary basis of the study of conscious vs. unconscious processing within academic psychology as a whole. On the other hand, if the answer is yes, it is unclear how to separate consciousness from

"cognitive elaborations." For example, if the term "cognitive elaborations" refers to processes such as concept-level recognition, maintenance/manipulation in working memory, and use in goal-directed decision making, then it should be highlighted that all of these processes contribute directly to the types of reporting behaviors that can uncontroversially confirm the existence of conscious experience. For this reason, multiple empirically supported neuro-cognitive models of consciousness (e.g., Dehaene et al., 2006; Prinz, 2012; Dehaene, 2014) claim that becoming conscious of a given thought/feeling specifically requires that the relevant representations are selectively made "accessible" to frontal-parietal networks associated with working memory and sequential, goal-directed cognition and action selection. Thus, if "raw feelings" are to remain empirically falsifiable in humans, they may not be fully separable from these types of interactions with goal-directed cognition (Prinz, 2007; Smith, 2016).

The ability for most behaviors (i.e., those that do not require the frontal-parietal working memory functions discussed above) to be affected in the absence of reportable experience also causes concerns with regard to how conscious feelings can be empirically verified in animals. That is, in combination with the fact that most animals cannot directly report their experiences, it raises important questions about how to appropriately extrapolate from the findings regarding conscious and unconscious processing in humans. We suggest that two empirical routes are plausible. First, if animals can be shown to use information after a delay period (requiring intentional working memory maintenance), then this would provide good reason to suspect that the animal was conscious of that information. Second, as specific neural signatures of conscious vs. unconscious processing have been discovered in humans (Bekinschtein et al., 2009; Dehaene, 2014; Melloni et al., 2007; Sergent and Naccache, 2012), if these signatures could also be detected in specific animal paradigms, then this would also provide evidence in favor of conscious awareness. There is no reason, in principle, that these techniques could not be applied to test whether an animal was conscious of its own emotional reaction in a given instance (although in practice there may be added difficulties).

In contrast to the above approaches, we suggest that the behavioral increases and decreases within the "Law of Affect" proposed by the AN perspective do not guarantee that an animal experienced a conscious feeling, or that only subcortical activation is required for conscious feelings. Our major question here is this: what evidence is there that behavioral increases/decreases cannot occur in the absence of conscious feelings? One major issue is that using the "Law of Affect" to argue that an animal necessarily had a conscious feeling appears to be circular. That is, to show that an animal had a conscious feeling it starts by observing behavioral increases/decreases, and it then labels the events leading to these behavioral changes as rewarding/punishing. Then it assumes that since these events are rewarding/punishing, this entails conscious feelings. Thus, this argument simply assumes that certain behavioral changes entail conscious feelings, and then it invalidly uses those behavioral changes as evidence for conscious feelings. Since, as reviewed above, it is widely known that many behavioral/learning effects can be elicited in the absence of conscious awareness, this assumption is also unwarranted. Unless it were shown conclusively, for example, that human behavior could not be reinforced/punished in the absence of reportable experience, this argumentative strategy will continue to lack a necessary premise. Since evidence also already exists suggesting that reinforcement/punishment can occur subliminally (e.g., Pessiglione et al., 2008) and even under general anesthesia (Bermudez-Rattoni et al., 1988; Burešová and Bureš, 1977; Millner and Palfai, 1975; Pang et al., 1996; Roll and Smith, 1972; Rozin and Ree, 1972), this appears unlikely.

This basic problem seems to be at the heart of some of the other arguments made by the AN perspective. As one example, in the case of experiments with decorticate animals, stereotyped emotional behaviors remain, and when triggered in response to subcortical DBS they can lead to behavioral changes associated with reinforcement-/punishment-based learning; based on this, the AN perspective argues that such animals must still have conscious feelings in response to subcortical DBS. Yet, it is clearly possible that such stereotyped behaviors remain present in the absence of conscious feelings – and this would actually be predicted by multiple leading models of conscious processing (Morsella et al., in press; Morsella, 2005; Prinz, 2012; Dehaene, 2014). Further, the evidence of successful emotional learning under general anesthesia discussed above suggests that the learned behavioral changes could also occur in response to DBS without a conscious feeling (Bermudez-Rattoni et al., 1988; Burešová and Bureš, 1977; Millner and Palfai, 1975; Pang et al., 1996; Roll and Smith, 1972; Rozin and Ree, 1972). As another example, the AN perspective argues that psychiatric benefits of medications targeting subcortical systems provide evidence in favor of their model. Yet, our recently proposed model makes the very same predictions (Smith and Lane, 2015), even though it does not assume that subcortical activation is sufficient for emotional experience. Clearly, chemically manipulating emotion generation processes ought to have an influence on those with psychiatric disorders, even if every emotion generation event is not necessarily consciously experienced. Thus these predictions are not unique to the model defended by the AN perspective, and are in fact shared by any model that assumes subcortical systems are relevant to emotion generation. Moreover, it is worth highlighting that PET imaging in the context of sadness clearly indicates that both subcortical and cortical areas are involved in changes in sadness experience as a function of mu opioid receptor occupancy (Zubieta et al., 2003; also see Smith et al., 2014).

Relatedly, JP&MS claim that the widespread belief that neocortex is essential for human consciousness has "long been contradicted by abundant data." Here, however, our question is as follows: what do you mean by "consciousness" in this context? We fully agree that subcortical structures are necessary to keep an individual in a wakeful/aroused state, in part because these regions keep cortical systems in an appropriate mode of processing. This meaning of "conscious" has been called "vigilance" within recent theoretical taxonomies (Dehaene et al., 2006), and is seen as a necessary (but not sufficient) condition for having any specific conscious experience. The vegetative state has also been specifically defined as wakefulness without awareness (Laureys, 2005), and therefore it appears to be a specific counterexample to the idea that wakefulness is sufficient for other types of consciousness. The type of "consciousness" that appears relevant to emotion, on the other hand, is instead the ability to become "conscious of" something (e.g., consciousness of the fact that one is sad, consciousness of one's unpleasantly tense posture, consciousness of one's desire to run away, etc.). Unlike simple wakefulness, to be conscious of specific information does appear to require cortex, because the cortex contains the representations of that information. For example, if certain regions of visual cortex are damaged, a person can cease to experience color (Cowey and Heywood, 1997), and that is because those cortical regions represent color. In a similar manner then, we have suggested that sufficient cortical damage could also remove one's ability to be conscious of one's own emotional reactions (Smith and Lane, 2015). However, given the distributed and hierarchical nature of cortical emotion representation, to remove consciousness of all the aspects (i.e., "building blocks") of a composite emotional reaction (e.g., bodily feelings, attentional/memory biases, activated conceptual knowledge, action tendencies, etc.) would likely require widespread bilateral damage to regions of

the insula, somatosensory cortex, medial prefrontal cortex, anterior and posterior cingulate, and lateral temporal cortex.

While the issues above are of primary importance, a few secondary issues are also worthy of brief mention. First, JP&MS are skeptical that neocortical processes can generate an emotional reaction "on their own." What this means is unclear. For example, regional electrical stimulation of the anterior cingulate has been shown to reliably trigger smiles/laughter in human case studies (Sperli et al., 2006). Further, there is evidence that voluntary emotion generation involves DMPFC (Kober et al., 2008); yet such effects are thought to involve interactions with subcortical regions that more proximally trigger the bodily/behavioral reactions and cognitive biases associated with emotion generation. So does the idea of cortical emotion generation need to operate without interactions with subcortical systems? If not, then cortical emotion generation appears to have evidential support. If so, on the other hand, we agree this is unlikely, given the very nature of emotional reactions as we define them. In general JP&MS should be clearer about what they take emotion generation to consist of, and how the various aspects of an emotional reaction (behavioral, autonomic, neuroendocrine, cognitive) are consciously perceived and understood. For example, while they discuss the emotion-generating effects of DBS on various subcortical circuits, they do not address how these circuits get activated in natural circumstances.

Second, it is important to highlight that AN's skepticism about cortical involvement in generating emotional responses appears to depend in part on their view that the cortex is an "unprogrammed" Tabula rasa at birth. From the CN perspective, this idea appears strongly exaggerated in light of existing evidence. That is, while the cortex is clearly a highly plastic organ, many considerations appear to support the idea that its development occurs under significant genetic/epigenetic constraints. These considerations include 1) its structural differentiation in terms of both cytoarchitecture and functional specialization (e.g., consistent visual, somatosensory, auditory, motor, and association areas), 2) the presence of stable and widespread functional networks (e.g., default mode, executive control, visual, auditory, etc.; Barrett and Satpute, 2013; Yeo et al., 2011), 3) observed genetic influences on cortical thickness/volume (Joshi et al., 2011), and 4) evidence suggesting the heritability of cortical activation patterns associated with particular cognitive functions (Blokland et al., 2011). Given such findings, it therefore remains plausible that cortex has sufficient heritable structure to contribute to innate/unconditioned emotional responses.

Third, JP&MS state that clear evidence from DBS has shown the existence of the 7 basic emotion circuits; yet, published critiques have strongly questioned the nature of this evidence and the way it is interpreted (Barrett et al., 2007a; also see published peer commentaries on Panksepp, 1982). Exactly what published evidence in peer-reviewed journals has been found to support each of these basic emotion circuits? It should be made clearer exactly what the nature of this evidence is, and why it supports the existence of the specific circuits AN describes. One reason to make clear what the relevant evidence is (and how it is interpreted) is that JP&MS do not always appear to interpret evidence in a consistent manner. For example, in the study by Shevrin et al. (2012), they argue that self-reported affective shifts are reliable indicators of conscious feelings during subliminal perception. However, they also argue elsewhere that self reports are unreliable indicators of affective phenomenology (e.g., they state above that "drugs which excite and inhibit the SEEKING and PANIC systems. . . produce almost comically variable cognitive-affective self reports"). Clearly it is inconsistent to appeal to self reports when they support the AN position, but to also deny the reliability of those same types of reports when they fit less well with AN theory. Thus, we suggest it will be important for the evidence supporting AN's 7 circuit model, and the way it is interpreted, to be clarified so that it can be assessed/evaluated in an unbiased manner.

Based on the discussion above, therefore, the major topics we believe the AN position should directly address can be grouped together into four basic, inter-related sets of questions:

#1. In general, what does "emotion generation" consist of according to AN? For example, does the idea that emotions "emerge" subcortically simply mean that emotional reactions (e.g., autonomic/somatomotor changes, cognitive/attentional biases) are generated by these structures? Or does it also mean that activity in these structures *alone* is sufficient for consciously experiencing those reactions?

#2. What do the terms "raw subjective feeling" and "cognitive elaborations" mean, and how can the distinction be tested? For example, how can the existence of a raw subjective feeling be empirically verified in humans? Is the absence of verbal/behavioral reports sufficient to disconfirm a raw subjective feeling? What evidence is there that the behavioral increases/decreases referred to in the proposed "Law of Affect" cannot occur in the absence of conscious feelings?

#3. Exactly what published evidence in peer-reviewed journals has been found to support each of the basic emotion circuits you defend?

#4. When the claim is made that cortex is not required for "consciousness," what does this term refer to? Does this simply refer to the state of wakefulness (in which conscious experiences are possible)? Or does it refer to being conscious of a particular type of experience (such as an emotional reaction)?

To conclude, this overall exchange is not simply an "empty" philosophical debate. As Solms and Turnbull point out, "subjectivity is us" and science has left subjectivity out (Solms and Turnbull, 2002). It is incredibly important to develop a science of subjectivity, which includes understanding its neural basis. We also agree with the AN perspective that when emotions are consciously accessible, they have unique effects on both thought and behavior, and hence, it is of great clinical relevance to understand exactly what effects are uniquely conferred by conscious access.

Further, whereas JP&MS point to the therapeutic implications of their work for biological psychiatry, we would point to the therapeutic implications of this debate for psychotherapy. It makes a difference whether therapists, psychiatrists and mental health clinicians assume that 1) affects are always conscious, except when defensive processes prevent them from becoming so, or whether 2) there are instead circumstances and conditions in which affect is generated but is not conscious, experienced, or known in any way, and that have nothing to do with motivated defense or the motivated avoidance of emotional pain (Lane et al., 2015b). All psychotherapeutic techniques have their successes but also their failures and the failures need to be better understood. We believe that the evidence supports the conclusion that affects are not always conscious, that subcortical activation alone is insufficient for conscious emotional experience, and that there are many reasons why emotion is not associated with conscious experience that have nothing to do with defenses. We further believe that when psychotherapists incorporate principles and implications of cognitive neuroscience into their technical repertoire, patients can benefit because they will be better understood. If patients can have the experience of being understood, and can be helped to better understand themselves, they will be in a much better position to incorporate critical emotional information into their conscious and automatic decision making and thus lead healthier and better adapted lives. (See Section 6 for the AN view's response to this critique.)

6. AN response to CN's critique and questions (JP & MS)

#1. In general, what does "emotion generation" consist of according to AN? For example, does the idea that emotions "emerge" subcortically simply mean that emotional reactions (e.g., autonomic/somatomotor changes, cognitive/attentional biases) are generated by these structures? Or does it also mean that activity in these structures *alone* is sufficient for consciously experiencing those reactions?

JP&MS: The AN view is based largely on the direct electrical (and neurochemical) stimulation of specific subcortical brain regions that mediate visually evident emotional-behavioral arousals (simple sine-wave current suffices at the low microampere range that humans cannot feel when applied to their fingertips). The fact that such DBS is "pure" electrical energy with no structured patterning resembling neuronal firing strongly supports the view that coherent brain emotional-behavioral states are evolutionarily organized in sub-cortical brain regions. Such dramatic evocation of emotional-behavioral shifts have never been observed by DBS of neocortex, although there is some positive data for DBS of cingulate, insular, and orbitofrontal cortices. Whether these states of distinct subcortical emotional arousals are accompanied by anything that could be called an emotional "feeling state" (namely positive or negative valences) can only be *inferred* in animal studies from evoked reward and punishment at brain sites where DBS evokes ethologically distinct emotional behavior patterns (e.g., exploration, attack, flight, copulation, maternal-care, separation-distress calls and rough-and-tumble juvenile ludic activities). To equate lack of feeling with lack of verbal report of feeling is tautological. In fact, even verbal reporting of a feeling is not robust objective evidence of the existence of that feeling. Valence is thus defined in such DBS-evoked brain-behavioral states as being either rewarding (e.g., self-stimulation of SEEKING, LUST, CARE, and PLAY sites) or punishing (FEAR, RAGE and PANIC). In short, such inferred affective state shifts have long been monitored in animals, ever since Olds and Milner (1954) and Delgado and colleagues (Delgado et al., 1954) first demonstrated the rewarding and punishing properties of DBS at diverse subcortical sites. Panksepp (1971) was among the first to map aggression-circuit sites in rats, and those that evoked "affective rage-like attack" (a behavioral manifestation of inferred angry feeling) were indexed by the fact that animals would learn to escape such states by pressing a lever. In contrast, the quiet-biting (predatory-type) attacks evoked from other hypothalamic sites, mainly in the MFB, were rewarding. Sites that evoked fearful-flight type behavioral arousals would also motivate the animal to escape those evoked states. There is an abundance of such papers in the literature, and we suggest a good starting point for a detailed coverage of early work in Panksepp (1981, 1982, 1998a), and a synopsis of related human studies in Panksepp (1985).

Since, to our knowledge, humans have no experienced emotional arousals without such valenced central-state shifts, we think it is scientifically coherent to ascribe affective states (potentially homologous if neuroanatomical and neurochemical homologies can be demonstrated) across mammalian species. Therefore, in answer to the question, yes, subcortical activation alone is sufficient for consciously experiencing valenced emotional states, but only in terms of the "*constitution*" of phenomenal consciousness (qualia/sentience) and not in terms of the "awareness" of access consciousness (i.e., CN's use of the term "awareness", a higher mental aspect of consciousness, remains difficult to study in animals). Of course, one cannot "ask" animals semantically whether the rewarding effects of one brain site are "identical" to rewarding effects from another site. However, we can ask whether animals can discriminate DBS to such different brain sites, and they can discriminate distinct rewarding sites when nearby brain regions (as in septum and MFB) are used as discriminative stimuli for making behavioral choices. In this context, it is especially important to note that when DBS of two very distant sites along the same pathway—namely, MFB—are used, animals do not discriminate the evoked positive states, but they do discriminate rewarding DBS sites in MFB and those in nearby septal regions (see Stutz et al., 1974).

Also relevant to the question of the locus of control for such affective feelings is the observation of complex emotional and related behaviors in decorticate animals (Kolb and Tees, 1990; Panksepp, 1993; Pellis and Pellis, 2013) as well as hydranencephalic children with cortical agenesis (Merker, 2007). Again, it is impossible to know in any absolute sense whether or not these emotional behaviors are accompanied by *precisely* the same kind of affective qualia as they are in corticated animals and children, but a reasonable provisional inference is that the feelings correspond in some consistent way to the aroused emotional-behavioral states. To assume that emotional behaviors are not associated with consciousness in decorticate animals and children is to *prejudge* the issue (to simply equate cortex with consciousness, on first principles, as has been done for the last two centuries). One empirically reasonable way to proceed in such circumstances (in both nonverbal humans and animals) is to make additional predictions based on the hypothesis that they *do* feel the relevant affects. The contextual relevance and appropriateness of the responses confirms these predictions: e.g., the hydranencephalic child 'fusses' when a toy is removed, laughs when it is returned, gets excited, with joyous facial expressions, when a baby brother is placed on her lap, etc. (Merker, 2007). What about other animals? Aside from human self-reports already noted, which are generally consistent with the above thesis (Panksepp, 1985), another relevant approach would be to test novel psychiatric predictions. That has been achieved to a modest extent for childhood autism (Bouvard et al., 1995) and robustly in the treatment of depression (for reviews, see Panksepp, 2015a; Panksepp et al., 2014).

#2. What do the terms "raw subjective feeling" and "cognitive elaborations" mean, and how can the distinction be tested? For example, how can the existence of a raw subjective feeling be empirically verified in humans? Is the absence of verbal/behavioral reports sufficient to disconfirm a raw subjective feeling? What evidence is there that the behavioral increases/decreases referred to in the proposed "Law of Affect" cannot occur in the absence of conscious feelings?

JP&MS: "Raw subjective feelings" is a vernacular way of saying an organism experiences affective qualia—namely subjectively valenced (e.g., desirable/pleasurable and undesirable/unpleasurable) sentient states. Again, one would have to use direct brain manipulations such as DBS or neuropharmacological manipulations that have been done extensively in animal models, and record not only explicit evoked emotional behaviors and autonomic changes, but also experiential state shifts as decoded through language in intact humans as well as the rewarding and punishing properties of such manipulations in other animals. Obviously well-controlled *constitutive* research on such topics is rarely possible in humans, which highlights why cross-species mammalian research is essential, especially in relevant subcortical brain regions where neural homologies abound (Panksepp, 2015a, 1998a). Such subcortical research is not routinely possible in humans. Of course, in humans, critical observations can be made in the midst of medically indicated/approved procedures, and there are abundant observations that DBS of various subcortical loci can evoke strong emotional feeling (and sometimes associated behavioral) responses in humans (Heath, 1996; Panksepp, 1985); there is also abundant evidence from human brain-imaging of subcortical neural correlates of emotion, which has been compiled by cognitive neuroscientists (e.g., Damasio et al., 2000 being one of the first compelling studies—because the PET environment allows evocation of strong emotional feelings from autobiographical reminiscences).

One other approach we have used has been to require research participants to indicate their feeling state on simple cartoon images depicting valence, arousal and surgency. Using this approach, we have demonstrated shifts in *affective* consciousness in response to wholly unconscious (subliminal) cognitive stimuli (Shevrin et al., 2012). We take this as evidence that affective qualia can be experienced, even though the precipitating cognitive stimuli are totally out of "awareness" (for a review of the affective blindsight literature, see Celeghin et al., 2015). As a corollary to this, it remains possible that the primary-process brain mechanisms for valenced affective feelings can still operate when cognitive "awareness" consciousness is gone (helping explain the various lines of evidence of learning under anesthesia which RS and RDL highlight).

With regard to human brain imaging, we would reemphasize that PET procedures/studies are substantially more relevant for imaging emotional feelings (e.g., Damasio et al., 2000; Hsu et al., 2013, 2015; Zubieta et al., 2003) than is fMRI. With fMRI procedures, due to the need for very exacting timing of stimuli and responses, it is not wise to harvest affective self-reports right after presentation of stimuli. For instance, cognitive judgments can inhibit subcortical arousals, as highlighted by the global see-saw effects of raw subcortical affects and cognitive elaborations (Liotti and Panksepp, 2004; Northoff et al., 2011, 2009). In one experiment that contrasted the harvesting of affective responses during ongoing brain scanning, as compared to post-session evaluation of recalled affective intensities, diametrically opposite results were observed (Northoff et al., 2009). When cognitive affect judgments were made right after the presentation of affective stimuli, there were negative correlations with subcortical arousals. However, if one harvested remembered (post scanning) affective shifts with subcortical arousals, the correlations were positive, suggesting that in fact the affective shifts were related more to subcortical than cortical arousals. In other words, making cognitive judgments during fMRI scanning, right after emotion provoking stimuli, seems to inhibit subcortical arousals.

Indeed, diverse, carefully constructed studies of cortical and subcortical responses during intense emotional arousals (as in simulated predator situations, where virtual predators actually "bite" the experimental subject; i.e., electric finger shock being the surrogate predator), one gets intense arousal in primary FEAR circuits such as in the PAG, while if the predator is at a greater distance, higher brain regions exhibit the most processing (Mobbs et al., 2007). This principle, we would suggest, will work well if adequate attention is paid to making the emotional feelings intense (may we say "real"?) as opposed to the many more modest affective shifts that are commonly studied in humans (e.g., to pictures of emotional facial expressions), partly no doubt, because of research ethics boards limiting the amount of stress that can be imposed on human research volunteers.

Similar ethical issues are increasingly being imposed on animal investigators (because the emerging consensus is that animals do experience a variety of aversive states during research using "punishers," which is consistent with our DBS data concerning aversive FEAR and RAGE sites (Panksepp, 1971), and with the evidence-based likelihood that animals are experiencing negative affect). Indeed, because of such ethical concerns, JP decided to devote practically all his research effort for the past three decades to the study of positive emotions, especially animal play and "laughter," and specifically focusing on how such work may help identify new psychiatric treatments (Burgdorf et al., 2016; Panksepp and Wright, 2012; Panksepp and Yovell, 2014; Panksepp, 2016, 2015a; Panksepp et al., 2014; Wright and Panksepp, 2012; Yovell et al., 2016). We believe our data-based predictions for various novel human therapeutics provide considerable weight of evidence for the cross-species affective strategies that we have been advocating and pursuing, and overall, the AN approach provides useful new avenues for understanding the corresponding affective feelings in humans. For instance, the DBS mapping of positively-valenced "rat laughter" sites (Burgdorf et al., 2007) has helped illuminate the circuitry for human laughter (Bilella et al., 2016), with diminution of laughter-type ultrasonics when those sites are damaged in rats (Roccaro-Waldmeyer et al., 2016). It is noteworthy that chronic subcortical DBS of the underlying SEEKING System in humans is robustly anti-depressive (Schlaepfer et al., 2013).

#3. Exactly what published evidence in peer-reviewed journals has been found to support each of the basic emotion circuits you defend?

JP&MS: This requires book-length treatment, as it has received in Panksepp (1998a) as well as in a host of long early reviews, most prominently Panksepp (1981, 1982) and Panksepp et al. (1988), as well as a variety of others (as below). These publications provide extensive bibliographies of the primary experimental literature in relation to each of the basic emotion circuits. In short, it is clear that brain sites that promote SEEKING, LUST, CARE and PLAY are highly rewarding. The first three are supported by the vast literature on the so-called (we would say poorly named) "The Brain Reward System" (mammalian brains have several distinct rewarding systems); indeed, evidence against a neocortical role for the constitution of those emotional action systems is that all those DBS evoked subcortical rewards and punishments and emotional behaviors survive radical neo-decortication (see Valenstein, 1966 and Huston and Borbely, 1973, 1974; and Panksepp et al., 1994 for survival of play following radical neo-decortication, and Kolb and Tees, 1990 for a comprehensive overview of decortication studies). We recognize the abundant data that insular, medial- and orbito-frontal cortices participate in various experiential aspects of emotionality, but we know little about whether these are evolutionarily-dictated or developmentally-programmed functions.

To emphasize, the most decisive evidence for the subcortical localization of emotional primes comes from the demonstration that radical decortication of neonatal rats (around 3 days of age, which spares some cortical regions ventral to the amygdala; i.e., before neocortical regions have been programmed by learning and memory), leaves basic emotional behavioral sequences intact – namely exploration/foraging, flight, various forms of aggression, sexuality, maternal care, and playfulness. The fact that the circuits mediating these affective-behavioral "tools for living" are subcortically concentrated seems definitive (especially if one considers that the rewarding and punishing effects of DBS remain robust after decortication, as noted earlier). If it were the case that the rewarding and punishing properties of subcortical DBS were severely impaired after decortication, the AN perspective on the subcortical *constitutional* origin of raw emotional qualia would be *severely* compromised. Reciprocally, what evidence is there to support the CN supposition that cortical processing is critically important for primal emotional feelings? We do not claim that affective feelings are not "cognitivized" by cortical learning and memory processes, yielding subtle emotional variants that can hardly be studied in animals (e.g., hope, regret, scorn, bemusement, etc), but simply that the cortical networks need the subcortical systems in order to add valence to the standard brain mechanisms of learning and memory (i.e., mechanisms of synaptic plasticity such as long-term potentiation, and state-dependent learning).

#4. When the claim is made that cortex is not required for "consciousness," what does this term refer to? Does this simply refer to the state of wakefulness (in which conscious experiences are possible)? Or does it refer to being conscious of a particular type of experience (such as an emotional reaction)?

JP&MS: We start from the observation that it feels like something to be awake, to be sentient. Wakefulness is not a purely quantitative state. We are not aware of any evidence for the existence of states of mind in humans where the subject reports (even

retrospectively) wakefulness without awareness of "being", of sentient existing, even though we accept that there are abundant ambiguities in this assertion (e.g., Laureys, 2005); we simply note that the experience of raw affective states appears to survive massive damage to cognitive "awareness," which in our estimation is a higher form of consciousness (for fuller discussion, see Panksepp et al., 2007). Thus we need to make distinctions between the *generation* (triggering) of and *constitution* of consciousness, which is empirically very difficult in human research. Conversely, we are not in a position to make as clear cognitive vs. affective distinctions of consciousness in animals as can be done in humans. Namely experienced cognitions cannot be as well studied in animals as their valenced feelings (but see Rygula et al., 2015; Steiner and Redish, 2014), because we can focus on rewarding and punishing brain states (i.e., empirical evidence for the existence of valenced affects) in animals receiving subcortical DBS along various neural pathways that evoke emotional action patterns. We would suggest that primal affects, which come in *emotional* (as already noted), *homeostatic* (e.g., THIRST and HUNGER with their respective SATIETYs) and *sensory* variants (e.g., diverse bodily PAINs and PLEASUREs), provide automatic survival indicators, highlighting why learned aversions and preferences emerge from the reinforcing dynamics of primal affective processes.

We would suggest that pure primary-process waking/consciousness always has an affective tinge of some kind, with SEEKING system-engendered feelings of enthusiasm being most pervasive. Such affective qualia may have been the first type of experiences in brain/mind evolutions. Thus, a bit more precisely, by primary "consciousness" we simply mean valenced "qualia," namely measureable shifts toward negative or positive affective subjective states (in non-speaking animals this can, so far, only be evaluated with rewarding and punishing DBS and neuropharmacologial studies), without any claims (because of the lack of relevant empirical evidence) about concurrent cognitive experiential shifts. We have no standardized techniques to monitor the cognitive qualia aspects of waking states in animals, but do have techniques to monitor distinct affective arousals. For us, what is especially important is that relevant animal studies have long shown (since Valenstein, 1966 and Huston and Borbely, 1973, 1974) that such rewarding and punishing effects of subcortical DBS survive massive decortication, suggesting (as do various human lesion studies) subcortical loci of control for the generation of intense emotional affects. See also the studies of hydranencephalic children cited above. The role typically assigned to prefrontal cortex (and various other cortical regions, especially insula) by those who believe neocortex is essential for constituting primal affective sentience – as opposed to higher-order "awareness" – is particularly strongly contradicted by everyday observations at the bedside of patients with massive frontal lobe injuries; these patients, if anything, are *excessively* emotional. See also Damasio and colleagues' observations on the unequivocal self-reported affective states of a patient with completely obliterated insular cortex (Damasio et al., 2013) – another favorite region cited by "cortico-centric" theorists of affective consciousness (e.g., see A. Craig, 2015 for such a paleocortical perspective). This is not to say that those areas do not re-represent and regulate a variety of higher affective processes. Surely they can.

In conclusion: For those who might still doubt the intrinsic affective/psychological powers of mammalian subcortical brain systems, let us share an experiment carried out in a student-lab practicum of one of the authors (JP) in the mid-1980s when his group started studying the robust social play of decorticate rats (for details, see Panksepp et al., 1994). There were 16 students in an affective neuroscience laboratory class, where beside regular lectures, students had 14 laboratory practicums on brain and behavior using laboratory rats. In the first week of the semester, JP prepared two animals for each student: one in which the neocortex had been aspirated away to give a clear view of the structures below (e.g., basal ganglia, septal area, and hippocampus; see Panksepp (1998a) pg. 292, Fig. 15 .6) and another control rat that also, at 3 days of age, had full sham surgery, with the whole brain left intact. During the final practicum, all students received a pair of such animals to observe individually, as they wished, for half an hour; their assignment was to decide which animal had been decorticated. JP expected random choices, but was surprised to find that 12 of 16 students chose their decorticate animal to be the neurologically intact, normal one (reflecting a $p < 0.05$ mistake by Chi square analysis). In debriefing, a common theme was that the 12 students who chose decorticates to be intact had made their mistaken choices largely on the basis of which animal explored more (without apparent anxiety) – namely the one that seemed more highly interested in the world – a manifestation of disinhibition of the highly "rewarding" subcortical SEEKING (enthusiasm) system. This probably simply reflected removal of cortical inhibition (higher regulation) of lower instinctual urges. Such animals also exhibit largely intact FEAR, RAGE, LUST and maternal CARE responses. Thus we would encourage cognitive neuroscientists to recognize that the current cross-species *weight of evidence* is that a close study of subcortical brain regions/networks is essential for understanding how raw human emotional feelings (primary-process affective qualia) are constituted (as discussed in Solms and Panksepp, 2012), a fact that is consistent with long established knowledge in neurology (Watt and Pincus, 2004).

Anyone who believes that primal emotional-affective states emerge via neocortical regions (although some regions, such as insula and medial prefrontal and orbitofrontal cortices, obviously contribute much to higher-order affective life) have a vast set of experimental challenges to explain concerning where and how human brains generate emotional-valuative states of mind (as well as unconditional emotional behaviors). We have no doubt that many neocortical regions participate in diverse higher-order behavioral and cognitive strategies related to affective arousals, better illuminated by human CN approaches, much of which simply cannot be well emulated with animal models. In contrast, animal models are essential for neurochemical and primal affective decoding of such systems. We anticipate that cognitive neuroscientists studying human affective mentality will eventually recognize that the neuro-evolutionary issue of "raw" *emotional* (as well as *homeostatic* and *sensory*) affects will never be "constitutionally" solved without the appropriate kind of "causal" research that requires direct interventions in evolutionarily coded subcortical circuits, which is obviously more easily pursued in animal models. In contrast, the cognitive triggering of affective states in humans is better illuminated by CN research. AN fully recognizes the true "Darwinian" power of animal brain research in helping solve the constitutional/foundational (primary-process) affective mysteries that the harvesting of brain correlates with modern human brain-imaging and EEG cannot yet address in compelling ways. CN is especially well situated to illuminate the more cognitive side of human mental life, much of which is guided by shifting affective states. The two approaches need to work together synergistically.

We expect, and always have, that the higher cortical cognitive processes can parse raw emotions into many higher-order emotional concepts/processes, many unique to humans (best studied by human CN and neuropsychoanalytic approaches), where animal research currently has few credible epistemological approaches. Many of the remarkable cognitive-affective strategies that human brains/minds can devise will be illuminated more by human CN strategies than cross-species AN approaches. Conversely, CN is not well situated to work out the neural *constitution* (the most relevant neural circuits and neurochemistries) of intense human emotional-affective experiences. Thus, we claim that there are

primary-process (evolved/"instinctual") emotional tools-for-living that were built into subcortical circuits of all mammalian brains (and many other genera of animals—see Huber et al., 2011), and the homologies that exist provide substantive empirical perspectives for generating neurochemical understanding of raw emotional feelings in humans, and thereby promote development of new psychiatric therapeutics (Panksepp and Yovell, 2014; Panksepp, 2016, 2015a; Panksepp et al., 2014; Yovell et al., 2016). We propose that there are levels of consciousness, such as the primary-process affective levels (e.g., the unconditioned feeling of pain and various other sensory, as well as emotional and homeostatic affects) that can, in fact, be experienced in decorticated animals, simply within the complexities of sub-neocortical circuits. We know of no evidence to suggest that subcortical affects are learned on the basis of generalized valence and arousal dimensions as postulated, a bit too earnestly, by constructivist approaches without supportive, constitutive neuroscience research (Barrett, 2006; for a AN critique, see Panksepp, 2008, 2007b, which highlights that social constructivist investigators should constrain their theorizing to human cortical thought-related processes, unless they have relevant/substantive subcortical evidence).

The AN approach is currently silent about the capacity of higher brain regions, especially the unique neocortical expansions (much of which arose from a few gene variants; see Florio et al., 2015), to engender higher-order feelings that require learning (features which may eventually yield diverse higher-order affective states in humans, perhaps even other species; Rygula et al., 2012; Steiner and Redish, 2014). Thus, cognitive-affective issues are much harder topics to address empirically through cross-species animal research, when compared to the neural nature of their native affective propensities. Of course the learning guided by primal emotions, such as FEAR conditioning, can be easily modeled in animals, often by investigators that deny that emotional feelings can be studied in animals (e.g., LeDoux, 2012; Rolls, 2005). However, despite the intrinsic difficulties in illuminating higher-order cognitive processes in animal models, from the AN perspective, human CN arguments against the power of cross-species AN approaches to illuminate the evolved affective foundations of animal (and thereby human) minds are not compelling. Conversely, cross-species AN has provided little illumination of human complex affective and cognitive proclivities and abilities. Development of better strategies for the AN and CN perspectives to work together toward possible shared goals will be more effective than either strategy pursued alone. For AN the key question is the neural constitution of raw emotional, homeostatic and sensory affects (with the best work on sensory affects coming from Kent Berridge's lab (e.g., Pecina et al., 2006)).

7. CN response to AN's critique and questions (RS & RDL)

Question #1 (Summarized). How does CN envision the evolutionary construction of the brain without an explicit "nested hierarchy" view?

RS&RDL: The CN perspective accepts that the brain is organized in a manner that can, at least in many contexts, be usefully described as hierarchical (Smith and Lane, 2015). Namely, we accept that both lateral and medial prefrontal regions, including anterior cingulate regions, can be understood to act as dynamic filtering mechanisms, *which can both amplify and suppress* the activation/influence of processes occurring elsewhere in the brain (Mitchell and Greening, 2011; Mitchell, 2011; Shimamura, 2000). This can include the selective amplification/suppression of processing within subcortical regions as well as within cortical sensory/memory systems. However, the CN perspective does not accept the three-level view described by AN (i.e., that affect = subcortical structures, learning/memory = basal ganglia and archi/paleo cortices, and cognition = neocortex). We instead hold that functions like "affect," "learning and memory," and "cognition" can only be properly understood in terms of interactions between multiple cortical and subcortical systems. This view leads to the empirically supported predictions, for example, that learning/memory processes also occur within neocortex (Friston, 2005; Nadel et al., 2012), that subcortical regions play important roles in cognition (Aron et al., 2007; Grahn et al., 2008; McNab and Klingberg, 2008), and that affective processes occur across all hierarchical levels in the AN taxonomy (Dayan and Daw, 2008; Silvetti et al., 2014; Smith and Lane, 2015; Smith et al., 2014).

From the CN perspective, the evolutionary view of the brain that AN describes may easily lead to misunderstandings that may not have been intended. Specifically, the AN view's three-level model can appear to imply that phylogenetically newer brain systems were simply built "on top of" older ones, and that the older (i.e., subcortical) ones did not change. The AN view understands this as a necessary oversimplification, but we are concerned that the content domains being over-simplified are the very domains relevant to certain disagreements between CN and AN. For example, in opposition to AN's simplified characterization, there is considerable evidence that phylogenetically older neural systems are subject to considerable restructuring in response to the development of more recent, hierarchically higher level systems (reviewed in Striedter, 2005). Essentially, as brains grow in size (encephalization) there is a need to reorganize at all levels to maintain coherent function. Therefore, we expect phylogenetically older (subcortical and cortical) structures to have somewhat altered structure/function in humans, as compared to other animals, in response to recent neocortical expansions (and in response to the evolutionary pressures that drove those expansions). Further, it is important to clarify that cortex in some form (i.e., pallium) is present in all vertebrates, and gene expression profiles also suggest strong affinities between the vertebrate pallium and the invertebrate mushroom bodies (Tomer et al., 2010). Thus, cortex/pallium itself should not be understood as a phylogenetically recent addition, but should instead be seen as an ancient adaptation whose structure/function also underwent re-organization (and expansion) in humans in response to selective pressures.[9] Given these facts, the CN perspective envisions partial, but not complete, homologies in both cortical and subcortical regions between humans and other species. Therefore, the degree to which subcortical systems (that generate emotional behavior in animals) play the same functional role in humans remains an open question. We suspect there are many similarities, but that there may also exist some important differences as well.

The CN perspective also accepts that many subcortical regions (e.g., the PAG, VTA, septal nuclei, hypothalamic nuclei, amygdala) should be understood to play an important role in affective processes. Specifically, many of them are capable of generating innate, patterned bodily reactions (both skeletomotor and visceromotor) in response to affective stimuli (Bandler and Shipley, 1994; Bandler et al., 2000; Brandão et al., 2008; Carli et al., 1963; Satpute et al., 2013), and many also modulate cortical/subcortical networks associated with attention, memory, and decision-making (Cools et al., 2011; Mather et al., 2015). While we accept that these are affective processes, we deny that they will necessarily result in experienced emotional states (which we suggest further requires representation and selection for global broadcasting, as described in our opening section). Further, we would highlight that the very

[9] The pallium of simpler creatures might therefore support the conscious experience of both external percepts (e.g., sights, sounds, smells) and internal percepts (e.g., visceral emotional responses) in a manner consistent with the findings of human studies on the neural correlates of consciousness (Dehaene, 2014).

reason these subcortical regions "count" as being affective in nature is that their activation has specific effects on cortical and subcortical targets (i.e., they have "affective" influences on the body, memory, and cognition). In other words, it is the interaction between regions/systems that more appropriately defines affective mental content/function.[10]

As one example, while the VTA dopamine system is described as a "SEEKING" system by AN, more recent computational neuroscience models (Niv et al., 2007) suggest that tonic dopamine levels report the expected rate of acquisition of utility (i.e., subjective reward), which influences action selection mechanisms within both prefrontal cortex and basal ganglia. Specifically, only if this rate is expected to be high will the predicted gains of exploration outweigh the costs of effort and metabolic expenditure, leading to the motivation to act in a more exploratory manner. However, without a cortex or basal ganglia for the dopamine system to "report to," it is possible that no behavioral evidence of increased "seeking" (or its reinforcing effects) would be available. This example highlights the importance of considering how subcortical nuclei influence the systems that receive the signals they send, and also illustrates how the emotional (in this case "enthusiastic") behavior associated with increased subcortical activation (in this case, tonic increases in dopamine) may be best understood as an influence of expectation on cortical and subcortical systems that govern the selection of one type of behavior over another.

Therefore, CN understands many subcortical nuclei to contribute to affective functions, but allows that not all affective processes at the subcortical level result in conscious emotional experience. Further, from the CN perspective, it is the effects that these nuclei have on cortical, subcortical, and bodily targets that endow them with this affective status. This includes effects on learning/memory as well as on cognitive control processes. However, because there is evidence that instrumental conditioning (and many other types of learning) can occur implicitly (e.g., Bermudez-Rattoni et al., 1988; Pang et al., 1996; Pessiglione et al., 2008; Reber, 2013), we do not believe that demonstration of reinforcement/punishment in animals conclusively demonstrates that conscious feelings are necessarily present. It is also worth highlighting that, even according to AN, such instrumental learning involves "secondary process" basal ganglia functions, so evidence of reinforcement/punishment ought to minimally require that their "primary process" activations interact with "secondary" basal ganglia processes (which themselves are intimately tied to prefrontal function; Cisek 2007; Redgrave et al., 1999). In summary, as opposed to a three-level nested hierarchy of "newer" cortical control regions on top of "older" subcortical emotion systems, the CN perspective understands functions like valence, learning and memory, decision-making, and cognitive control to be defined by complex interactions between cortical and subcortical regions that co-evolved into interactive networks, which jointly function to guide human behavior in a flexible, context-specific manner.

Question #2 and #3 (Summarized). How can CN help decode the neuro-anatomical/-physiological and neurochemical foundational mechanisms of human primal emotional-affective states? And how can CN (without an understanding of subcortically-mediated primal affects) develop new evidence-based neurobiological treatments for diverse affective disorders, where molecular refinements to treatments discovered by serendipity (rather than our explicit understanding of how brains generate affective states), have led the way?

RS&RDL: As highlighted in the dopamine example in our response above, we believe it is important to first characterize the computational function(s) of particular neurochemically defined anatomical systems. This requires gathering information from both human and animal studies (e.g., fMRI, PET, lesion studies, optogenetic/electrical stimulation, etc.), and using that information to arrive at coherent models; it then requires testing precise predictions of those models, including predictions relevant to therapeutic treatments. Importantly, even human neuroimaging methodologies – using machine learning algorithms – can go beyond mere correlation and test for specifically predictive relationships in a manner that can inform such "decoding" projects (Pereira et al., 2009). However, there is a sense in which it begs the question (i.e., that it assumes the truth of the conclusion being argued for) to ask *how* we will decode primal affective states, when part of the question involves the existence, and nature of, primal affects. To be clear, we do believe it is plausible that valence is innate, as positive/negative subjective value (i.e., utility) is a very basic necessity within a system like the brain – the evolutionary function of which is to select some bodily responses over others (i.e., those promoting the greatest fitness). However, we consider it an open question whether or not basic emotions categories (e.g., sadness, fear) map 1-to-1 to innately specified emotion generation circuits. As described in Section 3, many considerations suggest that such emotion categories are instead learned conceptual categories that are applied to different reactions in different contexts (LeDoux, 2012; Lindquist and Barrett, 2008; Wilson-Mendenhall et al., 2011), such as the observed variation in perceptual, cognitive, bodily, and self-reported aspects of categorical emotion episodes (e.g., different experiences that people all identify as fear; Barrett, 2006). For example, while there may be an innate action pattern for "fleeing," and another for "freezing," and while both may have negative valence (when experienced), neither of these would count as an innate "fear system." Instead, we would call both of them fear, and have some overlapping expectations as a result, due to learning that both patterns fall into one conceptual category. Thus, while we think that valence and innate action patterns have evolved, we consider it plausible that more specific emotion categories may be learned concepts. Nevertheless, the questions posed here remain unanswered. As such, it may be desirable for AN and CN to "join forces" to 1) define relevant circuits; 2) accept that conscious experience is not automatic; and 3) look for the neural signature of conscious processing in conjunction with activation of relevant circuits.

Question #4 (Summarized). How do you explain the regular variety of emotional responses with DBS at specific sites in decorticated animals (Huston and Borbely, 1973, 1974; Valenstein, 1966) and the many studies finding seemingly homologous responses in humans when stimulated at the same sites (Panksepp, 1985)? How can these two sets of findings be reconciled with the CN view that emotional feelings are generated cortically?

RS&RDL: From the CN perspective, emotions can be initiated either cortically or subcortically. However, cortical emotion generation will typically involve top-down activation of subcortical structures. Thus, subcortical regions are primary in the generation

[10] Part of this disagreement between AN and CN may also stem from the adoption of different philosophical theories of mind. Specifically, AN assumes a philosophical theory called "dual-aspect monism" (Solms and Turnbull, 2002), in that they assume that specific conscious affective states are the subjective aspect (the "being") of specific subcortical neural states which are their objective aspect. On this assumption, mental and physical states are the same constituent "thing", viewed from different observational perspectives. In contrast, however, CN instead assumes a philosophical theory of mind called "functionalism," which holds that "what makes something a mental state of a particular type does not depend on its internal constitution, but rather on the way it functions, or the role it plays, in the system of which it is a part" (http://plato.stanford.edu/entries/functionalism/). Thus, from this assumption, it instead makes sense to assume that conscious affective states will be linked to neural states based on their "role" in (or how they interact with) the rest of the larger brain system—and a neural state has an at least partially distinct role when it is selected for global broadcasting (i.e., made consciously accessible) compared to when it isn't.

of both the autonomic/somatic and the cognitive effects present during an emotional reaction. Further, as mentioned above, we agree that subcortical regions can generate coherent patterns of emotional behavior. Disagreement only arises because AN assumes that an emotional reaction is *always experienced* when it is generated. Instead, we claim **that for an emotional reaction to be experienced, it must subsequently be consciously perceived and recognized.** This involves, in part, consciously perceiving one's valenced interoceptive/somatic reactions. It further involves using contextual information and background knowledge to arrive at a conclusion regarding the conceptual meaning of those reactions. Based on leading neural models of consciousness (Dehaene, 2014; Morsella et al. in press), we hold that various PFC-dependent contextual and goal-related factors would determine whether these percept- and concept-level representations become consciously accessible; thus, based on such models, emotional reactions may or may not be consciously experienced, and these conscious experiences do require cortical participation. In addition to the large body of work supporting the models of consciousness we appeal to, in the realm of emotion this claim is further supported by previous studies which, for example, have illustrated that subcortical DBS in humans was only associated with conscious changes in mood if activation also spread to paralimbic/cortical regions (Stefurak et al., 2003).

Question #5 (Summarized). How does CN make sense of the surviving affective capacities of decorticate animals, hydranencephalic children, and humans with prefrontal and insular lesions?

RS&RDL: As JP&MS review, decorticate animals continue to display some coherent emotional behaviors (e.g., orienting, exploratory, appetitive, and defensive reactions). This is consistent with the idea (accepted by CN) that innately specified circuitry has evolved (in the remaining subcortical regions) to trigger the coordinated elements of such reactions in automated ways (i.e., presumably due to the added fitness conferred by the quick and reproducible use of such stereotyped reactions across particular types of recurring situations). However, as described above, the generation of such stereotyped responses does not by itself guarantee that these responses will be represented and globally broadcast; thus, it follows from the models of consciousness we appeal to that these reactions can be generated without necessarily being consciously experienced. Decorticate animals also retain basal ganglia regions implicated in instrumental conditioning, which should further allow for reward- and punishment-based learning to continue in response to these subcortically generated responses (i.e., an example of implicit learning). The functions decorticate animals should lack are the cortically mediated abilities to represent, consciously access, and maintain these subcortically generated emotional responses in working memory. Thus, from the CN perspective, the subcortical generation of these responses, and associated instrumental learning, would be expected to continue to occur in the absence of emotional experience in decorticate animals.

Our understanding of the case of hydranencephalic children is similar. If such children survive (typically requiring considerable medical intervention), they can eventually stabilize and come to display behaviors that meet neurological conditions for wakefulness (as might be expected given preserved brainstem/midbrain function). They also show automatic emotional responses to some perceptual stimuli, including emotional facial expressions, laughter, and crying (Merker, 2007). Such responses can also reflect instrumental learning (e.g., smiling in response to a familiar individual, learning to make particular movements associated with receiving a toy), which likely reflects intact subcortical circuitry associated with classical/operant conditioning. However, just as in the case of decorticate animals, these children lack the cortical networks that would allow the representation of their emotional responses, the selection of these representations for global broadcasting (and maintenance in working memory), and the ability for them to intentionally report (verbally or otherwise) on the experiences that they do and do not have. Their cognitive/behavioral repertoire therefore only allows the types of responses that do not definitively require conscious processing (for a recent review of the many processes/responses that can occur unconsciously, see Dehaene et al., 2014). Thus we suggest that this type of emotional learning/behavior can still happen unconsciously in such children. The situation is analogous to many other counterintuitive findings regarding "surprising" unconscious abilities (e.g., blindsight; Cowey, 2010), where it is difficult to imagine that some behaviors could remain in the absence of experience – but where the verbally reported absence of experience informs us otherwise. We should not assume that learning/behavior in this case – unlike in other cases – necessarily involves conscious experience simply because verbal reports are not available.

Finally, JP&MS have asked why, from the CN perspective, individuals with lesions to regions implicated in representing emotion do not cease to report emotional experience. A thorough treatment of this question would require examining the details of multiple individual case reports in more length than is possible here. Speaking generally, however, we find it important to highlight the distributed, hierarchical, and partially redundant/degenerate nature of cortical representation—and the difficulties this entails for inferring conclusions confidently from the types of lesion studies in question. According to our model (Smith and Lane, 2015) and related work (Barrett and Satpute, 2013), for example, an emotional response will be represented in different ways across several cortical areas with overlapping functions. These regions include (all bilaterally) the anterior and posterior insula, the anterior and posterior cingulate, MPFC, somatosensory cortex, and multiple regions of the temporal lobe. Some of these regions are involved largely in representing the bodily reactions themselves (e.g., insula, somatosensory cortex), and others are more involved in representing situational appraisals (e.g., ventromedial prefrontal cortex, dorsal anterior cingulate, anterior temporal cortex) and/or conceptual emotion categories (e.g., rACC, MPFC, lateral/medial temporal cortex, posterior cingulate). If all of these regions were ablated, the CN model would expect a lack of reported emotional experience. However damage to some of these regions but not others would be expected to instead involve at least partially preserved experience. For example, individuals with complete bilateral lesions to insular and somatosensory cortices bilaterally might be expected to lack reportable bodily feelings; even so, such individuals might still be able to represent concepts like sadness, for example, and report that sadness is associated with particular exteroceptive contexts (e.g., "the funeral of a loved one is sad"). Our answer to this question is therefore as follows. First, we are unaware of any lesion studies involving sufficiently widespread bilateral cortical damage to cause a reported lack of awareness regarding bodily feelings and emotion concepts according to our model. Second, the cases cited (Damasio et al., 2013; Feinstein et al., 2015) only involve limited damage to a few of these structures (i.e., bilateral insula, MPFC, and anterior cingulate damage in the most severe case), and would still be expected to spare sufficient representational capacities for retained verbal reports of the aspects of emotional experience tested.

8. Conclusions and future directions (jointly written by RS & RDL and JP & MS)

8.1. Overview of agreements, disagreements, and potential future experiments

The above discussion highlights important points of agreement and disagreement between the AN and CN perspectives. Some

major points of agreement are that healthy humans and other animals both often have conscious feelings, and that subcortical activation is necessary for the generation of primary conscious emotional experiences (qualia) in each. However, while both perspectives agree that subcortical circuits are *necessary*, there is disagreement with regard to *sufficiency*. That is, the AN perspective views subcortical activation alone as sufficient to generate affective experiential states, while the CN view holds that subcortical activation alone is insufficient. In addition to subcortical activation, CN holds that emotional experience also requires an emotional reaction to be subsequently perceived (via afferent feedback processes) and represented cortically (at perceptual and conceptual levels), and that these representations must then win a competition for conscious access. In other words, according to CN, the term "emotional experience" just refers to the conscious perception of one's own valenced bodily reaction (e.g., feeling pleasant warmth in one's face, feeling a lack of muscle tension), the conscious recognition of that reaction as a particular emotion (e.g., happy), and associated changes in conscious thought, attention, desire/motivation, and memory (e.g., attributing your happiness to a particular event, desiring more such events to occur in the future, remembering previous happy events, etc.). Thus, while the AN view holds that subcortically generated affects have a fundamental, privileged position in the mechanisms underlying conscious experience, the CN view instead understands "being conscious of an emotional reaction" as on par with (and involving the same mechanisms as) being conscious of any other representation in perception, cognition, and memory (and therefore CN also allows that one could consciously experience some of these represented aspects of an emotional reaction without experiencing others in a given instance; e.g., as in affective agnosia, Lane et al., 2015b).

One part of the disagreement described in the previous paragraph stems from a disagreement about the validity of specific inferences from behavior. While AN believes that observed reinforcement- and punishment-based influences on behavior warrant the inference that an experienced feeling was necessarily present (even in decorticate humans/animals), the CN view holds that such learning effects—while typically associated with a conscious feeling – may continue to occur unconsciously in the absence of intact cortical mechanisms (e.g., as suggested by studies of implicit learning in humans and animal learning under general anesthesia; Bermudez-Rattoni et al., 1988; Burešová and Bureš, 1977; Millner and Palfai, 1975; Pang et al., 1996; Reber, 2013; Roll and Smith, 1972; Rozin and Ree, 1972). Another part of this disagreement, however, instead stems from theoretical assumptions about consciousness. Specifically, the AN view distinguishes phenomenology and "awareness," allowing for the possibility of subjective experiences to which an individual does not have reflective access (and therefore could *not* report, even if they could speak). The CN view, in contrast, suggests that this distinction threatens to make claims about the presence/absence of phenomenology unfalsifiable (e.g., it would allow assertions that a person was currently having experiences that they honestly deny having), and instead suggests that phenomenology itself becomes present when conscious access occurs (i.e., that phenomenology is instead associated with the long-range interactions between brain regions associated with conscious access, and not with the activity of any particular brain region alone; see Baars et al., 2005; Smith, 2016).[11] Thus, according to CN, it would be better to start by establishing the measures that reliably indicate the presence/absence of phenomenology in humans (e.g., measuring the availability of perceptual/conceptual content to working memory), and then to work out ways of extrapolating these measures to animals (for a similar suggestion, see LeDoux, 2012). In contrast, AN asserts that a line of critical pragmatic importance is whether our understanding of the subcortical emotional system can positively impact human psychiatric therapeutics.

Another point of agreement between AN and CN is that subcortical emotion circuits are broadly evolutionarily homologous between humans and other mammals. However, while AN sees subcortical homologies as compelling and convincing, CN sees them as broadly suggestive but not determinative. Thus, while AN treats subcortical circuits as substantially homologous between humans and other mammals, CN sees abundant room for critical differences that can limit generalization between species. But, of course, both views accept that normative variability exists between species as well as between individuals of a species. CN therefore does not view these AN claims as wrong so much as not yet having sufficient evidence and remaining in need of additional testing. AN proposes that there is sufficient weight of evidence that various sub-neocortical primary emotional systems do exist in mammalian brains, but that there is currently inadequate evidence that certain higher brain regions widely implicated in emotional functions (e.g., cingulate and insula) can engender valenced feelings independently of subcortical emotional circuit influences. CN suggests that the "7 basic emotional circuits" model posited by AN should be the topic of additional testing using modern techniques in both humans and other animals, and that this model's predictions should be directly compared to predictions of competing models (e.g., Barrett and Satpute, 2013; Lindquist and Barrett, 2008; Smith and Lane, 2015). However, we acknowledge that much confusion has been caused by critics of AN overlooking the fact that the seven *emotional* circuits in question were never claimed to provide a comprehensive taxonomy of affects in general. To say the least, AN has always acknowledged the existence of myriad *homeostatic* and *sensory* affects – which have less relevance for psychiatry.

Further, AN and CN also appear to disagree about how affect generation circuits relate to conscious feelings. AN holds that each of the 7 emotional action circuits map onto particular emotional feelings in a direct and predictable manner (e.g., SEEKING promotes enthusiasm, RAGE promotes anger). In contrast, CN suggests that the mapping between emotion generation circuits and emotional feelings is more plausibly many-to-many (as opposed to 1-to-1); thus, the same circuit might lead to a different *reported* feeling in different contexts, and different circuits might also lead to the same reported feeling in certain contexts. Of course, AN has no problem with emotional mixtures arising, and yielding higher-order emotions, as a function of cultural differences and individual experiences, as well as the role of very nonspecific influences such as of ascending cholinergic, norepinephrine and serotonin systems. Thus, this disagreement between AN and CN is restricted to basic emotions, and does not apply to complex emotions.

There also appears to be an important disagreement between AN and CN regarding the domain of study addressed by each other. AN suggests that CN does not (and largely cannot) study the neural *constitution* of basic affects, and it portrays CN methods as

[11] However, CN recognizes that future methodologies/measures could (in principle) allow for ways to falsify claims about phenomenology without conscious access. The CN position is therefore that, unless/until this happens, there is no reason to be confident that phenomenology and access can come apart (i.e., because all currently reliable measures of phenomenal experience are either directly or indirectly correlated with goal-directed reporting behavior; see Smith, 2016). While the possibility of phenomenology without access can have intuitive appeal, the conservative position taken by CN appears warranted given that several recent findings (e.g., studies of change blindness; Simons and Rensink, 2005) suggest that we can highly overestimate how much we actually consciously perceive before directly attending to something (e.g., this has been referred to as the ğrand illusionẅithin the vision literature; Clark, 2002; Noe, 2002).

primarily correlational. CN, in contrast, suggests that human studies can effectively investigate basic affects (i.e., in addition to investigating more traditionally "cognitive" domains), and also emphasizes that some of its methods do allow for causal and predictive (as opposed to merely correlational) inferences (e.g., TMS, machine learning algorithms, human pharmacological manipulations, etc.). Relatedly, AN holds that the weight of evidence favors their position (e.g., from invasive animal studies and successful contributions to human psychopharmacology, based on animal findings); in contrast, CN holds that, because these results are also consistent with models allowing unconscious emotion, this evidence is equally supportive of both perspectives. Both groups ultimately believe, however, that combining forces, and using both sets of techniques together, will lead to the greatest future advances. Specifically, the discussion above highlights the possibility of designing joint experiments in both humans and animals that could directly provide added knowledge/insight pertaining to the points of disagreement we have identified.

One possible set of experiments in humans could involve testing the possibility of unconscious instrumental preference conditioning. While AN predicts that all cases of behaviorally detectable brain reinforcement/punishment effects in awake individuals should have conscious (valenced) feelings associated with them, CN suggests that reinforcing/punishing effects might occur without an experienced valence (i.e., no empirically verifiable change in subjective feeling would occur at the moment of exposure to the reinforcer/punisher). This could be examined, for example, by adapting existing paradigms for subliminal instrumental conditioning (e.g., Pessiglione et al., 2008). Such paradigms have shown that learning can occur without conscious experience of external stimuli (e.g., visual stimuli), but this leaves open the possibility that these subliminal stimuli still trigger conscious affective feelings (i.e., with positive/negative valence, as in: Celeghin et al., 2015; Shevrin et al., 2012). We suggest that this possibility could be further tested by adding continuous self-report measures of emotional state to such paradigms (e.g., a dial indicating changes in pleasantness, while recognizing that such actions may partially diminish/modify experienced affect). If changes in self-reported pleasantness, for example, were reliably observed during subliminal exposure to rewarding/punishing stimuli (e.g., subliminal exposure to happy and angry faces), this would support the AN model. If this was not observed, however, and later behavioral changes to the rewarding/punishing stimuli were still found, it would suggest that instrumental conditioning effects are not reliable evidence of conscious emotional experience (and thus more supportive of the CN model).[12]

A second set of experiments in humans could take advantage of the opportunity to stimulate subcortical regions directly. Specific clinical populations, such as patients with epilepsy and Parkinson's disease, allow for the ethical use of DBS at subcortical sites. While several studies have previously taken advantage of this opportunity (e.g., Lanteaume et al., 2007; Stefurak et al., 2003), none to our knowledge have been designed to specifically test the predictions of the AN view's 7-circuit model of basic emotions in humans, even though there is relevant clinical evidence (e.g., see Panksepp, 1985). In addition, the possibility of combining DBS and neuroimaging (i.e., PET) in this context provides an even greater potential opportunity to examine the neural correlates of conscious emotion. For example, if one first identified subcortical stimulation intensities that reliably do and do not induce self-reported changes in emotion (but where both intensities trigger other physiological changes; e.g., changes in heart rate), one could then administer stimulations at both of those intensities again in the scanner while patients were simply instructed to rest (i.e., no required cognitive reflection). This would allow a neuroimaging contrast of conscious vs. unconscious effects of subcortical stimulation that should not be confounded by the cognitive reflections/elaborations (and their inhibition of subcortical dynamics) that concern the AN view. The CN model predicts that conscious (relative to unconscious) stimulations would show widespread frontal-parietal cortical involvement, even though no self-reports are being acquired during stimulation and scanning. The AN view would instead expect primarily subcortical involvement (i.e., some cortical arousals due to stimulation would be expected since cholinergic, norepinephrine and serotonin cortical arousal control systems could be activated, but this would be expected to occur at both stimulation intensities, and should not have consciousness-specific frontal-parietal effects as CN would predict).

There are also a range of possible experiments that could be done in animals. One possibility is that more recent state-of-the-art methods for structurally characterizing and stimulating subcortical regions could be employed to further test whether 7 distinct subcortical emotion circuits are actually present (for example, see Anderson, 2012; Tovote et al., 2015; Urban and Roth, 2015). Selective ibotenic acid lesions to the PAG in rats (that spare crossing white matter pathways; e.g., Winn et al., 1984) could also be done to further test AN's proposed relation between this structure and both wakefulness and emotional learning.

Another interesting possibility is that reliable physiological indicators of consciousness in humans could be tested in animals using affective paradigms. Specifically, it has been shown in several human studies that there are four reliable physiological signatures that can reliably predict when a perceived stimulus will and will not be consciously experienced (e.g., Del Cul et al., 2009; Gaillard et al., 2009; Melloni et al., 2007: reviewed in Dehaene, 2014 Ch. 4). These include (1) a specific pattern of increased frontal-parietal activation (using neuroimaging), (2) the appearance of a late slow electrical potential called the "P3 wave" (using EEG), (3) a late, sudden burst of high frequency (gamma) oscillations (when recording from individual neurons intra-cranially), and (4) a large-scale increase in synchronous activity (indexing increased information exchange) between anterior and posterior regions of the brain (as could be assessed, for example, through magnetoencephalography and neuroimaging-based functional connectivity analyses). There is no reason, in principle, that the same measures could not be used to test for conscious access to an emotional response in animals. For example, one could subliminally present an animal with stimuli known to have reinforcing or punishing effects, and test for the presence of each of these signatures during this subliminal presentation of the reinforcer/punisher. If one showed that instrumental conditioning was successful, and one also failed to detect these physiological signatures, this would support the CN position that emotional responses can sometimes occur unconsciously. In contrast, if these signatures were observed, it would support the AN view that primal (instinctual) emotional responses are always experienced.

In short, we suggest that the most productive way forward is for AN and CN to join forces in order to (1) define the relevant subcortical emotion circuits further in terms of anatomical discreteness and overlap, and further determine how they relate to self-reported human emotional feelings; (2) further examine the issue of whether emotional reactions are always (or only sometimes) consciously experienced; and (3) establish agreed upon neural signature of conscious emotional experience in both humans and animals in parallel studies.

[12] A similar study might also be conceivably carried out in non-human animals by using training regimes requiring animals to report behaviorally on their putative experiences (together with statistical and objective criteria being used to obtain behavioral correlates of consciousness in animals; see Boly et al., 2013).

8.2. Summary of points of agreement and disagreement

8.2.1. Agreements

1. We agree that subcortical activation is necessary for generating affective experiential states.
2. We agree that subcortical circuits are broadly similar (homologous) between humans and other mammals.
3. We agree that other mammals (with intact cortex) do have diverse conscious (experienced) affective *emotional*, *homeostatic*, and *sensory* feelings.
4. We agree that both AN and CN approaches are not simply correlational, and both can, in principle, elucidate the neuroconstitutional nature of human affective states.
5. We agree that invasive research methods on subcortical processes are limited in human beings, and animal models are therefore essential for illuminating many of the underlying neural details.
6. We agree that neocortical processes alone, without interactions with subcortical processes, are insufficient to generate affective/emotional reactions, and that archi- and paleo-cortical networks are essential for the full complexity of affective feelings. We also agree that neocortex can instigate and regulate emotional feelings.
7. We agree that the most progress will occur if AN and CN work together in the future, with integration of their respective methodologies.

8.2.2. Disagreements

1. We disagree regarding whether subcortical activation alone is sufficient to generate affective experiential states (i.e., CN holds that subcortical processes are necessary but not sufficient for affective experience, whereas AN holds that subcortical activation is both necessary and sufficient for primitive, namely primary-process, affective experience).
2. We disagree regarding whether cognitive and affective consciousness involve different mechanisms (i.e., from the CN view, all types of consciousness involve the same global broadcasting mechanism; from the AN view, the ancestral survival indicators of affective consciousness are more ancient, and based on sub-neocortical network dynamics that are sufficient to generate various valenced states of mind).
3. We disagree regarding whether rewarding and punishing electrical and chemical DBS, as measured by associated behavioral approach and escape responses, is evidence for experienced affective feelings in decorticate animals and hydranencephalic humans (i.e., CN holds that this type of emotional learning/behavior could occur unconsciously in the absence of cortex, whereas AN instead holds that these behavioral changes are good evidence of conscious feelings even in the absence of cortex).
4. We disagree regarding whether qualia can be present in the absence of access consciousness (i.e., AN proposes that affective phenomenology can exist in sub-neocortical brain dynamics without reflective "awareness" of that phenomenology, whereas CN suggests that phenomenology is instead associated with the long-range cortical interactions associated with global broadcasting and access consciousness).
5. We disagree regarding whether the weight of empirical evidence currently supports the 7-basic-emotion-circuits model of AN. Likewise, we disagree regarding whether the weight of evidence supports the CN view that neocortical activity changes are essential for affective feelings to occur.
6. Thus, we disagree regarding whether subcortical activity is both necessary and sufficient to generate affective experiential states. AN posits that subcortical activity is both necessary and sufficient. CN posits that subcortical arousals are necessary but not sufficient.
7. We disagree regarding whether human CN alone can empirically elucidate the constitution of primary process sensory, homeostatic, and emotional affects. Likewise, we disagree regarding whether AN methods alone are sufficient to provide the foundational information for how mammalian (including human) brains generate basic (unconditioned) affective experiences.

Of course we agree that neuroscientific understanding of affect should be able to provide knowledge for the development of new psychiatric treatments. We trust that our discussion will allow other interested investigators to not only situate their own work in the context of this debate, but all of us to pursue this difficult but essential topic in integrative ways that help illuminate the neural mechanisms of emotional feelings and other affective states that have so far eluded consensual/definitive neuroscientific understanding. It is only by empirically dealing with such contentious issues that lasting understanding in this difficult field will emerge.

References

Adolphs, R., Damasio, H., Tranel, D., Cooper, G., Damasio, A., 2000. A role for somatosensory cortices in the visual recognition of emotion as revealed by three-dimensional lesion mapping. J. Neurosci. 20, 2683–2690.

Alexander, B., Hadaway, P., 1982. Opiate addiction: the case for an adaptive orientation. Psychol. Bull. 92, 367–381, http://dx.doi.org/10.1037/0033-2909.92.2.367.

Andersen, R., Cui, H., 2009. Intention, action planning, and decision making in parietal-frontal circuits. Neuron 63, 568–583, http://dx.doi.org/10.1016/j.neuron.2009.08.028.

Anderson, D., 2012. Optogenetics, sex, and violence in the brain: implications for psychiatry. Biol. Psychiatry 71, 1081–1089, http://dx.doi.org/10.1016/j.biopsych.2011.11.012.

Aron, A., Durston, S., Eagle, D., Logan, G., Stinear, C., Stuphorn, V., 2007. Converging evidence for a fronto-basal-ganglia network for inhibitory control of action and cognition. J. Neurosci. 27, 11860–11864, http://dx.doi.org/10.1523/JNEUROSCI.3644-07.2007.

Baars, B., Laureys, S., Block, N., Baars, B.J., Dehaene, S., Laureys, S., 2005. One, not two, neural correlates of consciousness. Trends Cogn. Sci. 9, 269, http://dx.doi.org/10.1016/j.tics.2005.04.008, author reply 270.

Baars, B., 2005. Global workspace theory of consciousness: toward a cognitive neuroscience of human experience. Prog. Brain Res. 150, 45–53.

Bandler, R., Shipley, M.T., 1994. Columnar organization in the midbrain periaqueductal gray: modules for emotional expression? Trends Neurosci. 17, 379–389, http://dx.doi.org/10.1016/0166-2236(94)90047-7.

Bandler, R., Keay, K.A., Floyd, N., Price, J., 2000. Central circuits mediating patterned autonomic activity during active vs. passive emotional coping. Brain Res. Bull. 53, 95–104, http://dx.doi.org/10.1016/S0361-9230(00)00313-0.

Bargh, J., Morsella, E., 2008. The unconscious mind. Perspect. Psychol. Sci. 3, 73–79, http://dx.doi.org/10.1111/j.1745-6916.2008.00064.x.

Barrett, L., Satpute, A., 2013. Large-scale brain networks in affective and social neuroscience: towards an integrative functional architecture of the brain. Curr. Opin. Neurobiol. 23, 361–372, http://dx.doi.org/10.1016/j.conb.2012.12.012.

Barrett, L., Simmons, W., 2015. Interoceptive predictions in the brain. Nat. Rev. Neurosci. 16, 419–429, http://dx.doi.org/10.1038/nrn3950.

Barrett, L., Lindquist, K., Bliss-Moreau, E., Duncan, S., Gendron, M., Mize, J., Brennan, L., 2007a. Of mice and men: natural kinds of emotions in the mammalian brain? a response to panksepp and izard. Perspect. Psychol. Sci. 2, 297–312, http://dx.doi.org/10.1111/j.1745-6916.2007.00046.x.

Barrett, L., Mesquita, B., Ochsner, K., Gross, J., 2007b. The experience of emotion. Annu. Rev. Psychol. 58, 373–403, http://dx.doi.org/10.1146/annurev.psych.58.110405.085709.

Barrett, L., Mesquita, B., Gendron, M., 2011. Context in emotion perception. Curr. Dir. Psychol. Sci. 20, 286–290, http://dx.doi.org/10.1177/0963721411422522.

Barrett, L., 2006. Are emotions natural kinds? Perspect. Psychol. Sci. 1, 28–58, http://dx.doi.org/10.1111/j.1745-6916.2006.00003.x.

Bekinschtein, T., Dehaene, S., Rohaut, B., Tadel, F., Cohen, L., Naccache, L., 2009. Neural signature of the conscious processing of auditory regularities. Proc. Natl. Acad. Sci. U. S. A. 106, 1672–1677, http://dx.doi.org/10.1073/pnas.0809667106.

Bekkedal, M., Rossi, J., Panksepp, J., 2011. Human brain EEG indices of emotions: delineating responses to affective vocalizations by measuring frontal theta event-related synchronization. Neurosci. Biobehav. Rev. 35, 1959–1970, http://dx.doi.org/10.1016/j.neubiorev.2011.05.001.

Bermudez-Rattoni, F., Forthman, D., Sanchez, M., Perez, J., Garcia, J., 1988. Odor and taste aversions conditioned in anesthetized rats. Behav. Neurosci. 102, 726–732, http://dx.doi.org/10.1037/0735-7044.102.5.726.

Bilella, A., Alvarez-Bolado, G., Celio, M., 2016. The Foxb1-expressing neurons of the ventrolateral hypothalamic parvafox nucleus project to defensive circuits. J. Comp. Neurol., http://dx.doi.org/10.1002/cne.24057.
Block, N., 1995. A confusion about the function of consciousness. Behav. Brain Sci. 18, 227–247.
Block, N., 2005. Two neural correlates of consciousness. Trends Cogn. Sci. 9, 46–52, http://dx.doi.org/10.1016/j.tics.2004.12.006, S1364-6613(04)00318-3[pii].
Blokland, G., McMahon, K., Thompson, P., Martin, N., de Zubicaray, G., Wright, M., 2011. Heritability of working memory brain activation. J. Neurosci. 31, 10882–10890, http://dx.doi.org/10.1523/JNEUROSCI.5334-10.2011.
Boly, M., Seth, A., Wilke, M., Ingmundson, P., Baars, B., Laureys, S., Edelman, D., Tsuchiya, N., 2013. Consciousness in humans and non-human animals: recent advances and future directions. Front. Psychol. 4, 625, http://dx.doi.org/10.3389/fpsyg.2013.00625.
Bouvard, M., Leboyer, M., Launay, J.-M., Recasens, C., Plumet, M.-H., Waller-Perotte, D., Tabuteau, F., Bondoux, D., Dugas, M., Lensing, P., Panksepp, J., 1995. Low-dose naltrexone effects on plasma chemistries and clinical symptoms in autism: a double-blind, placebo-controlled study. Psychiatry Res. 58, 191–201, http://dx.doi.org/10.1016/0165-1781(95)02601-R.
Brandão, M.L., Zanoveli, J.M., Ruiz-Martinez, R.C., Oliveira, L.C., Landeira-Fernandez, J., 2008. Different patterns of freezing behavior organized in the periaqueductal gray of rats: association with different types of anxiety. Behav. Brain Res. 188, 1–13, http://dx.doi.org/10.1016/j.bbr.2007.10.018.
Brosch, T., Sander, D., 2013. The appraising brain: towards a neuro-cognitive model of appraisal processes in emotion. Emot. Rev. 5, 163–168, http://dx.doi.org/10.1177/1754073912468298.
Burešová, O., Bureš, J., 1977. The effect of anesthesia on acquisition and extinction of conditioned taste aversion. Behav. Biol. 20, 41–50, http://dx.doi.org/10.1016/S0091-6773(77)90473-4.
Burgdorf, J., Wood, P., Kroes, R., Moskal, J., Panksepp, J., 2007. Neurobiology of 50-kHz ultrasonic vocalizations in rats: electrode mapping, lesion, and pharmacology studies. Behav. Brain Res. 182, 274–283, http://dx.doi.org/10.1016/j.bbr.2007.03.010.
Burgdorf, J., Panksepp, J., Moskal, J., 2011. Frequency-modulated 50 kHz ultrasonic vocalizations: a tool for uncovering the molecular substrates of positive affect. Neurosci. Biobehav. Rev. 35, 1831–1836, http://dx.doi.org/10.1016/j.neubiorev.2010.11.011.
Burgdorf, J., Moskal, J., Brudzynski, S., Panksepp, J., 2013. Rats selectively bred for low levels of play-induced 50 kHz vocalizations as a model for autism spectrum disorders: a role for NMDA receptors. Behav. Brain Res. 251, 18–24, http://dx.doi.org/10.1016/j.bbr.2013.04.022.
Burgdorf, J., Colechio, E., Stanton, P., Panksepp, J., 2016. Positive emotional learning induces resilience to depression: a role for NMDA receptor-mediated synaptic plasticity. Curr. Neuropharmacol.
Cacciamani, L., Mojica, A., Sanguinetti, J., Peterson, M., 2014. Semantic access occurs outside of awareness for the ground side of a figure. Atten. Percept. Psychophys., http://dx.doi.org/10.3758/s13414-014-0743-y.
Carli, G., Malliani, A., Zanchetti, A., 1963. Midbrain course of descending pathways mediating sham rage behavior. Exp. Neurol. 7, 210–223, http://dx.doi.org/10.1016/0014-4886(63)90055-4.
Celeghin, A., de Gelder, B., Tamietto, M., 2015. From affective blindsight to emotional consciousness. Conscious. Cogn. 36, 414–425, http://dx.doi.org/10.1016/j.concog.2015.05.007.
Cisek, P., 2007. Cortical mechanisms of action selection: the affordance competition hypothesis. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 362, 1585–1599, http://dx.doi.org/10.1098/rstb.2007.2054.
Clark, A., 2002. Is seeing all it seems? Action, reason and the grand illusion. J. Conscious. Stud. 9, 181–202.
Coenen, V., Panksepp, J., Hurwitz, T., Urbach, H., Mädler, B., 2012. Human medial forebrain bundle (MFB) and anterior thalamic radiation (ATR): imaging of two major subcortical pathways and the dynamic balance of opposite affects in understanding depression. J. Neuropsychiatry Clin. Neurosci. 24, 223–236.
Cools, R., Nakamura, K., Daw, N., 2011. Serotonin and dopamine: unifying affective, activational, and decision functions. Neuropsychopharmacology 36, 98–113, http://dx.doi.org/10.1038/npp.2010.121.
Cowey, A., Heywood, C., 1997. Cerebral achromatopsia: colour blindness despite wavelength processing. Trends Cogn. Sci. 1, 133–139, http://dx.doi.org/10.1016/S1364-6613(97)01043-7.
Cowey, A., 2010. The blindsight saga. Exp. Brain Res. 200, 3–24, http://dx.doi.org/10.1007/s00221-009-1914-2.
Craig, A.D., 2009. How do you feel?now? The anterior insula and human awareness. Nat. Rev. Neurosci. 10, 59–70.
Craig, A., 2015. How Do You Feel? Princeton University Press, Princeton, NJ.
Critchley, H., Mathias, C., Josephs, O., O'Doherty, J., Zanini, S., Dewar, B.-K., Cipolotti, L., Shallice, T., Dolan, R., 2003. Human cingulate cortex and autonomic control: converging neuroimaging and clinical evidence. Brain 126, 2139–2152, http://dx.doi.org/10.1093/brain/awg216.
Damasio, A., Grabowski, T.J., Bechara, A., Damasio, H., Ponto, L.L., Parvizi, J., Hichwa, R.D., 2000. Subcortical and cortical brain activity during the feeling of self-generated emotions. Nat. Neurosci. 3, 1049–1056, http://dx.doi.org/10.1038/79871.
Damasio, A., Damasio, H., Tranel, D., 2013. Persistence of feelings and sentience after bilateral damage of the insula. Cereb. Cortex 23, 833–846, http://dx.doi.org/10.1093/cercor/bhs077.
Damasio, A., 2010. Self Comes to Mind: Constructing the Conscious Brain. Pantheon, New York.
Dayan, P., Daw, N., 2008. Decision theory, reinforcement learning, and the brain. Cogn. Affect. Behav. Neurosci. 8, 429–453, http://dx.doi.org/10.3758/CABN.8.4.429.
Dehaene, S., Changeux, J., Naccache, L., Sackur, J., Sergent, C., 2006. Conscious, preconscious, and subliminal processing: a testable taxonomy. Trends Cogn. Sci. 10, 204–211, http://dx.doi.org/10.1016/j.tics.2006.03.007.
Dehaene, S., Charles, L., King, J.-R., Marti, S., 2014. Toward a computational theory of conscious processing. Curr. Opin. Neurobiol. 25, 76–84.
Dehaene, S., 2014. Consciousness and the Brain. Viking Press.
Del Cul, A., Dehaene, S., Reyes, P., Bravo, E., Slachevsky, A., 2009. Causal role of prefrontal cortex in the threshold for access to consciousness. Brain 132, 2531–2540, http://dx.doi.org/10.1093/brain/awp111.
Delgado, J., Roberts, W., Miller, N., 1954. Learning motivated by electrical stimulation of the brain. Am. J. Physiol. 179, 587–593.
Denton, D., McKinley, M., Farrell, M., Egan, G., 2009. The role of primordial emotions in the evolutionary origin of consciousness. Conscious. Cogn. 18, 500–514, http://dx.doi.org/10.1016/j.concog.2008.06.009.
Denton, D., 2006. The Primordial Emotions: The Dawning of Consciousness. Oxford University Press.
Deyo, R., Panksepp, J., Abbott, B., 1990. Perinatal decortication impairs performance on an 8-arm radial maze task. Physiol. Behav. 48, 55–60, http://dx.doi.org/10.1016/0031-9384(90)90260-B.
Dror, O., 1999. The affect of experiment: the turn to emotions in Anglo-American physiology, 1900–1940. Isis 90, 205–237, http://dx.doi.org/10.1086/384322.
Dunbar, R., 2010. Coevolution of neocortical size, group size and language in humans. Behav. Brain Sci. 16, 681, http://dx.doi.org/10.1017/S0140525X00032325.
Dunbar, R., 2012. Bridging the bonding gap: the transition from primates to humans. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 367, 1837–1846, http://dx.doi.org/10.1098/rstb.2011.0217.
Eisenberger, N., 2010. The neuronal basis of social pain: findings and implications. In: MacDonald, G., Jensen-Campbell, L. (Eds.), Social Pain: Neuropsychological and Health Implications of Loss and Exclusion. American Psychological Association, Washington DC, pp. 53–78.
Fabbro, F., Aglioti, S., Bergamasco, M., Clarici, A., Panksepp, J., 2015. Evolutionary aspects of self- and world consciousness in vertebrates. Front. Hum. Neurosci. 9, 157, http://dx.doi.org/10.3389/fnhum.2015.00157.
Feinberg, T., 2011. The nested neural hierarchy and the self. Conscious. Cogn. 20, 4–15, http://dx.doi.org/10.1016/j.concog.2010.09.016.
Feinberg, T.E., Mallatt, J., 2016. The nature of primary consciousness. New Synth. 43, 113–127.
Feinstein, J., Khalsa, S., Salomons, T., Prkachin, K., Frey-Law, L., Lee, J., Tranel, D., Rudrauf, D., 2015. Preserved emotional awareness of pain in a patient with extensive bilateral damage to the insula, anterior cingulate, and amygdala. Brain Struct. Funct., http://dx.doi.org/10.1007/s00429-014-0986-3.
Feuillet, L., Dufour, H., Pelletier, J., 2007. Brain of a white-collar worker. Lancet 370, 262.
Florio, M., Albert, M., Taverna, E., Namba, T., Brandl, H., Lewitus, E., Haffner, C., Sykes, A., Wong, F., Peters, J., Guhr, E., Klemroth, S., Prüfer, K., Kelso, J., Naumann, R., Nüsslein, I., Dahl, A., Lachmann, R., Pääbo, S., Huttner, W., 2015. Human-specific gene ARHGAP11 B promotes basal progenitor amplification and neocortex expansion. Science 347, 1465–1470, http://dx.doi.org/10.1126/science.aaa1975 (80-.).
Fotopoulou, A., Pfaff, D., Conway, E., 2012. Trends in neuropsychoanalysis: psychology. In: Psychoanalysis and Cognitive Neuroscience in Dialogue. Oxford University Press, Oxford.
Fries, P., 2005. A mechanism for cognitive dynamics: neuronal communication through neuronal coherence. Trends Cogn. Sci. 9, 474–480, http://dx.doi.org/10.1016/j.tics.2005.08.011.
Friston, K., 2005. A theory of cortical responses. Philos. Trans. R. Soc. Lond. B. Biol. Sci. 360, 815–836, http://dx.doi.org/10.1098/rstb.2005.1622.
Gaillard, R., Dehaene, S., Adam, C., Clémenceau, S., Hasboun, D., Baulac, M., Cohen, L., Naccache, L., 2009. Converging intracranial markers of conscious access. PLoS Biol. 7, e61, http://dx.doi.org/10.1371/journal.pbio.1000061.
Grahn, J., Parkinson, J., Owen, A., 2008. The cognitive functions of the caudate nucleus. Prog. Neurobiol. 86, 141–155, http://dx.doi.org/10.1016/j.pneurobio.2008.09.004.
Gu, X., Hof, P., Friston, K., Fan, J., 2013. Anterior insular cortex and emotional awareness. J. Comp. Neurol. 521, 3371–3388, http://dx.doi.org/10.1002/cne.23368.
Haber, S., Knutson, B., 2010. The reward circuit: linking primate anatomy and human imaging. Neuropsychopharmacology 35, 4–26, http://dx.doi.org/10.1038/npp.2009.129.
Haidt, J., 2012. The Righteous Mind. Knopf Doubleday Publishing Group.
Hassin, R.R., Uleman, J.S., Bargh, J.A., 2005. The New Unconscious, Oxford Series in Social Cognition and Social Neuroscience. Oxford University Press, Oxford; New York.
Heath, R., 1996. Exploring the Mind-Body Relationship. Moran Printing, Baton Rouge, LA.
Herman, B., Panksepp, J., 1981. Ascending endorphin inhibition of distress vocalization. Science 211, 1060–1062, http://dx.doi.org/10.1126/science.7466377 (80-.).
Hohwy, J., 2014. The Predictive Mind. Oxford University Press.
Hornak, J., Bramham, J., Rolls, E., Morris, R., O'Doherty, J., Bullock, P., Polkey, C., O'Doherty, J., Bullock, P., Polkey, C., 2003. Changes in emotion after

circumscribed surgical lesions of the orbitofrontal and cingulate cortices. Brain 126, 1691–1712.
Hsu, D., Sanford, B., Meyers, K., Love, T., Hazlett, K., Wang, H., Ni, L., Walker, S., Mickey, B., Korycinski, S., Koeppe, R., Crocker, J., Langenecker, S., Zubieta, J.-K., 2013. Response of the μ-opioid system to social rejection and acceptance. Mol. Psychiatry 18, 1211–1217, http://dx.doi.org/10.1038/mp.2013.96.
Hsu, D., Sanford, B., Meyers, K., Love, T., Hazlett, K., Walker, S., Mickey, B., Koeppe, R., Langenecker, S., Zubieta, J.-K., 2015. It still hurts: altered endogenous opioid activity in the brain during social rejection and acceptance in major depressive disorder. Mol. Psychiatry 20, 193–200, http://dx.doi.org/10.1038/mp.2014.185.
Huber, R., Panksepp, J., Nathaniel, T., Alcaro, A., Panksepp, J., 2011. Drug-sensitive reward in crayfish: an invertebrate model system for the study of SEEKING, reward, addiction, and withdrawal. Neurosci. Biobehav. Rev. 35, 1847–1853, http://dx.doi.org/10.1016/j.neubiorev.2010.12.008.
Huston, J., Borbely, A., 1973. Operant conditioning in forebrain ablated rats by use of rewarding hypothalamic stimulation. Brain Res. 50, 467–472, http://dx.doi.org/10.1016/0006-8993(73)90753-1.
Huston, J., Borbely, A., 1974. The thalamic rat: general behavior, operant learning with rewarding hypothalamic stimulation, and effects of amphetamine☆. Physiol. Behav. 12, 433–448, http://dx.doi.org/10.1016/0031-9384(74)90121-8.
Johnston, E., Olson, L., 2015. The Feeling Brain: The Biology and Psychology of Emotions. W. W Norton.
Joshi, A., Leporé, N., Joshi, S., Lee, A., Barysheva, M., Stein, J., McMahon, K., Johnson, K., de Zubicaray, G., Martin, N., Wright, M., Toga, A., Thompson, P., 2011. The contribution of genes to cortical thickness and volume. Neuroreport 22, 101–105, http://dx.doi.org/10.1097/WNR.0b013e3283424c84.
Kalisch, R., Wiech, K., Critchley, H.D., Dolan, R.J., 2006. Levels of appraisal: a medial prefrontal role in high-level appraisal of emotional material. Neuroimage 30, 1458–1466, http://dx.doi.org/10.1016/j.neuroimage.2005.11.011.
Kennedy, S., Koeppe, R., Young, E., Zubieta, J.-K., 2006. Dysregulation of endogenous opioid emotion regulation circuitry in major depression in women. Arch. Gen. Psychiatry 63, 1199–1208, http://dx.doi.org/10.1001/archpsyc.63.11.1199.
Kiefer, M., Barsalou, L., 2013. Grounding the human conceptual system in perception, action, and internal states. In: Prinz, W., Beisert, M., Herwig, A. (Eds.), Action Science: Foundations of an Emerging Discipline. MIT Press, Cambridge, MA, pp. 381–407.
Kihlstrom, J., Mulvaney, S., Tobias, B., Tobis, I., 2000. The emotional unconscious. In: Eich, E., Kihlstrom, J., Bower, G., Forgas, J., Niedenthal, P. (Eds.), Cognition and Emotion. Oxford University Press, New York, pp. 30–86.
Kober, H., Barrett, L., Joseph, J., Bliss-Moreau, E., Lindquist, K., Wager, T.D., 2008. Functional grouping and cortical-subcortical interactions in emotion: a meta-analysis of neuroimaging studies. Neuroimage 42, 998–1031.
Kolb, B., Tees, R., 1990. The Cerebral Cortex of the Rat. MIT Press, Cambridge, MA.
Koob, G., Volkow, N., 2010. Neurocircuitry of addiction. Neuropsychopharmacology 35, 217–238, http://dx.doi.org/10.1038/npp.2009.110.
Lane, R., Nadel, L., 2000. Cognitive Neuroscience of Emotion. Oxford University Press.
Lane, R., Ryan, L., Nadel, L., Greenberg, L., 2015a. Memory reconsolidation, emotional arousal and the process of change in psychotherapy: new insights from brain science. Behav. Brain Sci. 38, e1.
Lane, R., Weihs, K., Herring, A., Hishaw, A., Smith, R., 2015b. Affective agnosia: expansion of the alexithymia construct and a new opportunity to integrate and extend Freud's legacy. Neurosci. Biobehav. Rev., http://dx.doi.org/10.1016/j.neubiorev.2015 06.007, in press.
Lane, R., 2008. Neural substrates of implicit and explicit emotional processes: a unifying framework for psychosomatic medicine. Psychosom. Med. 70, 214–231.
Lanteaume, L., Khalfa, S., Régis, J., Marquis, P., Chauvel, P., Bartolomei, F., 2007. Emotion induction after direct intracerebral stimulations of human amygdala. Cereb. Cortex 17, 1307–1313.
Laureys, S., 2005. The neural correlate of (un)awareness: lessons from the vegetative state. Trends Cogn. Sci. 9, 556–559, http://dx.doi.org/10.1016/j.tics.2005.10.010.
LeDoux, J., 2012. Rethinking the emotional brain. Neuron 73, 653–676, http://dx.doi.org/10.1016/j.neuron.2012.02.004.
Levine, H., 2012. The colourless canvas Representation, therapeutic action and the creation of mind. Int. J. Psychoanal. 93, 607–629.
Levy, R., Goldman-Rakic, P., 2000. Segregation of working memory functions within the dorsolateral prefrontal cortex. Exp. Brain Res. 133, 23–32.
Lewis, D., Misanin, J., Miller, R., 1968. Recovery of memory following amnesia. Nature 220, 704–705, http://dx.doi.org/10.1038/220704a0.
Lindquist, K., Barrett, L., 2008. Constructing emotion: the experience of fear as a conceptual act. Psychol. Sci. 19, 898–903, http://dx.doi.org/10.1111/j.1467-9280.2008.02174.x.
Lindquist, K., Wager, T., Kober, H., Bliss-Moreau, E., Barrett, L., 2012. The brain basis of emotion: a meta-analytic review. Behav. Brain Sci. 35, 121–143, http://dx.doi.org/10.1017/S0140525X11000446.
Liotti, M., Panksepp, J., 2004. On the neural nature of human emotions and implications for biological psychiatry. In: Panksepp, J. (Ed.), Textbook of Biological Psychiatry. Wiley, New York, pp. 33–74.
Mather, M., Clewett, D., Sakaki, M., Harley, C., 2015. Norepinephrine ignites local hot spots of neuronal excitation: how arousal amplifies selectivity in perception and memory. Behav. Brain Sci., 1–100, http://dx.doi.org/10.1017/S0140525X15000667.
McClelland, J., Rumelhart, D., 1981. An interactive activation model of context effects in letter perception: I. An account of basic findings. Psychol. Rev. 88, 375–407.
McNab, F., Klingberg, T., 2008. Prefrontal cortex and basal ganglia control access to working memory. Nat. Neurosci. 11, 103–107, http://dx.doi.org/10.1038/nn2024.
Melloni, L., Molina, C., Pena, M., Torres, D., Singer, W., Rodriguez, E., 2007. Synchronization of neural activity across cortical areas correlates with conscious perception. J. Neurosci. 27, 2858–2865, http://dx.doi.org/10.1523/JNEUROSCI.4623-06.2007.
Mendl, M., Burman, O., Paul, E., 2010. An integrative and functional framework for the study of animal emotion and mood. Proc. Biol. Sci. 277, 2895–2904, http://dx.doi.org/10.1098/rspb.2010.0303.
Merker, B., 2007. Consciousness without a cerebral cortex: a challenge for neuroscience and medicine. Behav. Brain Sci. 30, 63–81, http://dx.doi.org/10.1017/S0140525X07000891, discussion 81–134.
Mesquita, B., Frijda, N., 1992. Cultural variations in emotions: a review. Psychol. Bull. 112, 179–204, http://dx.doi.org/10.1037/0033-2909.112.2.179.
Millner, J., Palfai, T., 1975. Metrazol impairs conditioned aversion produced by LiCl: a time dependent effect. Pharmacol. Biochem. Behav. 3, 201–204, http://dx.doi.org/10.1016/0091-3057(75)90149-5.
Misanin, J., Miller, R., Lewis, D., 1968. Retrograde amnesia produced by electroconvulsive shock after reactivation of a consolidated memory trace. Science 160, 554–555, http://dx.doi.org/10.1126/science.160.3827.554 (80-.).
Mitchell, D., Greening, S., 2011. Conscious perception of emotional stimuli: brain mechanisms. Neuroscience 18, 386–398, http://dx.doi.org/10.1177/1073858411416515.
Mitchell, D., 2011. The nexus between decision making and emotion regulation: a review of convergent neurocognitive substrates. Behav. Brain Res. 217, 215–231, http://dx.doi.org/10.1016/j.bbr.2010.10.030.
Mobbs, D., Petrovic, P., Marchant, J., Hassabis, D., Weiskopf, N., Seymour, B., Dolan, R., Frith, C., 2007. When fear is near: threat imminence elicits prefrontal-periaqueductal gray shifts in humans. Science 317, 1079–1083, http://dx.doi.org/10.1126/science.1144298 (80-.).
Morsella, E., Godwin, C., Jantz, T., Krieger, S., Gazzaley, A., n.d. Homing in on Consciousness in the Nervous System: An Action-Based Synthesis. Behav. Brain Sci. in press.
Morsella, E., 2005. The function of phenomenal states: supramodular interaction theory. Psychol. Rev. 112, 1000–1021, http://dx.doi.org/10.1037/0033-295X.112.4.1000.
Nadel, L., Hupbach, A., Gomez, R., Newman-Smith, K., 2012. Memory formation, consolidation and transformation. Neurosci. Biobehav. Rev. 36, 1640–1645, http://dx.doi.org/10.1016/j.neubiorev.2012.03.001.
Niv, Y., Daw, N., Joel, D., Dayan, P., 2007. Tonic dopamine: opportunity costs and the control of response vigor. Psychopharmacology (Berl). 191, 507–520, http://dx.doi.org/10.1007/s00213-006-0502-4.
Noe, A., 2002. Is the visual world a grand illusion? J. Conscious. Stud. 9, 1–12.
Northoff, G., Schneider, F., Rotte, M., Matthiae, C., Tempelmann, C., Wiebking, C., Bermpohl, F., Heinzel, A., Danos, P., Heinze, H.-J., Bogerts, B., Walter, M., Panksepp, J., 2009. Differential parametric modulation of self-relatedness and emotions in different brain regions. Hum. Brain Mapp. 30, 369–382, http://dx.doi.org/10.1002/hbm.20510.
Northoff, G., Wiebking, C., Feinberg, T., Panksepp, J., 2011. The resting-state hypothesis of major depressive disorder-a translational subcortical-cortical framework for a system disorder. Neurosci. Biobehav. Rev. 35, 1929–1945, http://dx.doi.org/10.1016/j.neubiorev.2010.12.007.
Nummenmaa, L., Glerean, E., Hari, R., Hietanen, J.K., 2014. Bodily maps of emotions. Proc. Natl. Acad. Sci. U. S. A. 111, 646–651, http://dx.doi.org/10.1073/pnas.1321664111.
Olds, J., Milner, P., 1954. Positive reinforcement produced by electrical stimulation of septal area and other regions of rat brain. J. Comp. Physiol. Psychol. 47, 419–427.
Pang, R., Turndorf, H., Quartermain, D., 1996. Pavlovian fear conditioning in mice anesthetized with halothane. Physiol. Behav. 59, 873–875, http://dx.doi.org/10.1016/0031-9384(95)02137-X.
Panksepp, J., Bishop, P., 1981. An autoradiographic map of (3H) diprenorphine binding in rat brain: effects of social interaction. Brain Res. Bull. 7, 405–410, http://dx.doi.org/10.1016/0361-9230(81)90038-1.
Panksepp, J., Biven, L., 2012. The Archaeology of Mind: Neuroevolutionary Origins of Human Emotions. W.W Norton & Company, New York.
Panksepp, J., Wright, J., 2012. On SEEKING: A Foundational source of affective, behavioral and cognitive enthusiasm, volition, and will-power. Neuropsychoanalysis 14, 59–75.
Panksepp, J., Yovell, Y., 2014. Preclinical modeling of primal emotional affects (Seeking, Panic and Play): gateways to the development of new treatments for depression. Psychopathology 47, 383–393, http://dx.doi.org/10.1159/000366208.
Panksepp, J., Herman, B., Conner, R., Bishop, P., Scott, J., 1978. The biology of social attachments: opiates alleviate separation distress. Biol. Psychiatry 13, 607–618.
Panksepp, J., Bean, N., Bishop, P., Vilberg, T., Sahley, T., 1980. Opioid blockade and social comfort in chicks. Pharmacol. Biochem. Behav. 13, 673–683, http://dx.doi.org/10.1016/0091-3057(80)90011-8.
Panksepp, J., Normansell, L., Herman, B., Bishop, P., Crepeau, L., 1988. Neural and neurochemical control of the separation distress call. In: Newman, J.D. (Ed.),

The Physiological Control of Mammalian Vocalization. Springer, US, Boston, MA, MA, pp. 263–300, http://dx.doi.org/10.1007/978-1-4613-1051-8.
Panksepp, J., Normansell, L., Cox, J., Siviy, S., 1994. Effects of neonatal decortication on the social play of juvenile rats. Physiol. Behav. 56, 429–443, http://dx.doi.org/10.1016/0031-9384(94)90285-2.
Panksepp, J., Nocjar, C., Burgdorf, J., Huber, R., 2004. The role of emotional systems in addiction: a neuroethological perspective. In: Bevins, R., Bardo, M. (Eds.), Nebraska Symposium on Motivation. Lincoln, Nebraska, Nebraska, pp. 85–126.
Panksepp, J., Fuchs, T., Garcia, V., Lesiak, A., 2007. Does any aspect of mind survive brain damage that typically leads to a persistent vegetative state? Ethical Considerations. Philos. Ethics, Humanit. Med. 2, http://dx.doi.org/10.1186/1747-5341-2-32.
Panksepp, J., Wright, J., Dobrossy, M., Schlaepfer, T., Coenen, V., 2014. Affective neuroscience strategies for understanding and treating depression: from preclinical models to three novel therapeutics. Clin. Psychol. Sci. 2, 472–494, http://dx.doi.org/10.1177/2167702614535913.
Panksepp, J., 1971. Aggression elicited by electrical stimulation of the hypothalamus in albino rats. Physiol. Behav. 6, 321–329, http://dx.doi.org/10.1016/0031-9384(71)90163-6.
Panksepp, J., 1972. Hypothalamic radioactivity after intragastric glucose-14C in rats. Am. J. Physiol. 223, 396–401.
Panksepp, J., 1974. Hypothalamic regulation of energy balance and feeding behavior. Fed. Proc. 33, 1150–1165.
Panksepp, J., 1981. Hypothalamic integration of behavior: rewards, punishments, and related psychobiological process. In: Morgane, P., Panksepp, J. (Eds.), Handbook of the Hypothalamus. Marcel Dekker, New York, pp. 289–487.
Panksepp, J., 1982. Toward a general psychobiological theory of emotions. Behav. Brain Sci. 5, 407–467.
Panksepp, J., 1985. Mood changes. In: Vinken, P., Bruyn, G., Klawans, H. (Eds.), Handbook of Clinical Neurology. Elsevier, Amsterdam, pp. 271–285.
Panksepp, J., 1993. Neurochemical control of moods and emotions: amino acids to neuropeptides. In: Lewis, M., Haviland, J. (Eds.), Handbook of Emotions. Guilford Press, New York NY, pp. 87–107.
Panksepp, J., 1998a. Affective Neuroscience: The Foundations of Human and Animal Emotions. Oxford University Press.
Panksepp, J., 1998b. The periconscious substrates of consciousness: affective states and the evolutionary origins of the SELF. J. Conscious. Stud. 5, 566–582.
Panksepp, J., 2004. A Textbook of Biological Psychiatry. Wiley, New York.
Panksepp, J., 2005. Affective consciousness: core emotional feelings in animals and humans. Conscious. Cogn. 14, 30–80, http://dx.doi.org/10.1016/j.concog.2004.10.004.
Panksepp, J., 2007a. Can PLAY diminish ADHD and facilitate the construction of the social brain? J. Can. Acad. Child Adolesc. Psychiatry = J. l'Académie Can. Psychiatr. l'enfant l'adolescent 16, 57–66.
Panksepp, J., 2007b. Neurologizing the psychology of affects: how appraisal-Based constructivism and basic emotion theory can coexist. Perspect. Psychol. Sci. 2, 281–296, http://dx.doi.org/10.1111/j.1745-6916.2007.00045.x.
Panksepp, J., 2008. Cognitive conceptualism—where have all the affects gone? additional corrections for Barrett et al. (2007). Perspect. Psychol. Sci. 3, 305–308, http://dx.doi.org/10.1111/j.1745-6924.2008.00081.x.
Panksepp, J., 2010a. Energy is delight: the affective pleasures and pains of brain system for eating and energy regulation. In: Dube, L., Bechara, A., Drewnowski, A., LeBel, P., James, P., Yada, R. (Eds.), Obesity Prevention Handbook. Academic Press, London, pp. 5–14.
Panksepp, J., 2010b. Affective neuroscience of the emotional BrainMind: evolutionary perspectives and implications for understanding depression. Dialogues Clin. Neurosci. 12, 533–545.
Panksepp, J., 2011a. Cross-species affective neuroscience decoding of the primal affective experiences of humans and related animals. PLoS One 6, e21236, http://dx.doi.org/10.1371/journal.pone.0021236.
Panksepp, J., 2011b. Empathy and the laws of affect. Science 334, 1358–1359, http://dx.doi.org/10.1126/science.1216480 (80-.).
Panksepp, J., 2012. The vicissitudes of preclinical psychiatric research: justified abandonment by big pharma? Future Neurol. 7, 113–115, http://dx.doi.org/10.2217/fnl.12.1.
Panksepp, J., 2015a. Affective preclinical modeling of psychiatric disorders: taking imbalanced primal emotional feelings of animals seriously in our search for novel antidepressants. Dialogues Clin. Neurosci. 17, 363–379.
Panksepp, J., 2015b. The neuroevolutionary sources of mind. The ancestral constitution of affective consciousness and the core-SELF. In: Miller, S. (Ed.), The Constitution of Phenomenal Consciousness: Toward a Science and Theory (Advances in Consciousness Research, Vol. 92. John Benjamins Publishing Company, Amsterdam, pp. 226–259.
Panksepp, J., 2016. The cross-mammalian neurophenomenology of primal emotional affects: from animal feelings to human therapeutics. J. Comp. Neurol. 524, 1624–1635.
Pecina, S., Smith, K., Berridge, K., 2006. Hedonic hot spots in the brain. Neuroscience 12, 500–511, http://dx.doi.org/10.1177/1073858406293154.
Peelen, M., Atkinson, A., Vuilleumier, P., 2010. Supramodal representations of perceived emotions in the human brain. J. Neurosci. 51, 10127–10134, http://dx.doi.org/10.1523/JNEUROSCI.2161-10.2010.
Pellis, S., Pellis, V., 2013. The Playful Brain: Venturing to the Limits of Neuroscience. Oneworld Publications.
Pereira, F., Mitchell, T., Botvinick, M., 2009. Machine learning classifiers and fMRI: a tutorial overview. Neuroimage 45, S199–S209, http://dx.doi.org/10.1016/j.neuroimage.2008.11.007.
Pessiglione, M., Petrovic, P., Daunizeau, J., Palminteri, S., Dolan, R., Frith, C., 2008. Subliminal instrumental conditioning demonstrated in the human brain. Neuron 59, 561–567, http://dx.doi.org/10.1016/j.neuron.2008.07.005.
Pobric, G., Jefferies, E., Lambon Ralph, M., 2010. Category-specific versus category-general semantic impairment induced by transcranial magnetic stimulation. Curr. Biol. 20, 964–968, http://dx.doi.org/10.1016/j.cub.2010.03.070.
Prinz, J., 2002. Furnishing the Mind: Concepts and Their Perceptual Basis. MIT Press, Cambridge, MA.
Prinz, J., 2007. Accessed, accessible, and inaccessible: where to draw the phenomenal line. Behav. Brain Sci. 30, 521–522, http://dx.doi.org/10.1017/S0140525X07003020.
Prinz, J., 2012. The Conscious Brain: How Attention Engenders Experience (Philosophy of Mind). Oxford University Press, USA.
Reber, P., 2013. The neural basis of implicit learning and memory: a review of neuropsychological and neuroimaging research. Neuropsychologia 51, 2026–2042, http://dx.doi.org/10.1016/j.neuropsychologia.2013.06.019.
Redgrave, P., Prescott, T., Gurney, K., 1999. The basal ganglia: a vertebrate solution to the selection problem? Neuroscience 89, 1009–1023, http://dx.doi.org/10.1016/S0306-4522(98)00319-4.
Roccaro-Waldmeyer, D., Babalian, A., Müller, A., Celio, M., 2016. Reduction in 50-kHz call-numbers and suppression of tickling-associated positive affective behaviour after lesioning of the lateral hypothalamic parvafox nucleus in rats. Behav. Brain Res. 298, 167–180, http://dx.doi.org/10.1016/j.bbr.2015.11.004.
Roll, D., Smith, J., 1972. Conditioned taste aversion in anesthetized rats. In: Seligman, M., Hager, J. (Eds.), Biological Boundaries of Learning. Appleton-Century-Crofts, New York, pp. 98–102.
Rolls, E., 2005. Emotion Explained. Oxford University Press, Oxford, UK.
Rolls, E., 2013. Emotion and Decision-making Explained. Oxford University Press, Oxford.
Rolls, E., 2014. Emotion and decision-making explained: a précis. Cortex 59, 185–193, http://dx.doi.org/10.1016/j.cortex.2014.01.020.
Roux, F., Uhlhaas, P., 2014. Working memory and neural oscillations: alpha–gamma versus theta–gamma codes for distinct WM information? Trends Cogn. Sci. 18, 16–25.
Roy, M., Shohamy, D., Wager, T.D., 2012. Ventromedial prefrontal-subcortical systems and the generation of affective meaning. Trends Cogn. Sci. 16, 147–156, http://dx.doi.org/10.1016/j.tics.2012.01.005, S1364-6613(12)00027-7[pii].
Rozin, P., Ree, P., 1972. Long extension of effective CS-US interval by anesthesia between CS and US. J. Comp. Physiol. Psychol. 80, 43–48, http://dx.doi.org/10.1037/h0032831.
Russell, J., 1991. Culture and the categorization of emotions. Psychol. Bull. 110, 426–450, http://dx.doi.org/10.1037/0033-2909.110.3.426.
Rygula, R., Pluta, H., Popik, P., 2012. Laughing rats are optimistic. PLoS One 7, e51959, http://dx.doi.org/10.1371/journal.pone.0051959.
Rygula, R., Golebiowska, J., Kregiel, J., Kubik, J., Popik, P., 2015. Effects of optimism on motivation in rats. Front. Behav. Neurosci. 9, 32, http://dx.doi.org/10.3389/fnbeh.2015.00032.
Sahley, T., Panksepp, J., 1987. Possible brain opioid involvement in disrupted social intent and language development of autism. In: Schopler, E., Mesibov, G.B. (Eds.), Neurobiological Issues in Autism. Springer, US, Boston, MA, MA, pp. 357–372, http://dx.doi.org/10.1007/978-1-4899-1992-2.
Sanguinetti, J., Allen, J., Peterson, M., 2014. The ground side of an object: perceived as shapeless yet processed for semantics. Psychol. Sci. 25, 256–264, http://dx.doi.org/10.1177/0956797613502814.
Satpute, A.B., Wager, T., Cohen-Adad, J., Bianciardi, M., Choi, J.-K., Buhle, J.T., Wald, L.L., Barrett, L., 2013. Identification of discrete functional subregions of the human periaqueductal gray. Proc. Natl. Acad. Sci. U. S. A. 110, 17101–17106, http://dx.doi.org/10.1073/pnas.1306095110.
Schlaepfer, T., Bewernick, B., Kayser, S., Mädler, B., Coenen, V., 2013. Rapid effects of deep brain stimulation for treatment-resistant major depression. Biol. Psychiatry 73, 1204–1212, http://dx.doi.org/10.1016/j.biopsych.2013.01.034.
Sergent, C., Naccache, L., 2012. Imaging neural signatures of consciousness: what, when, where and how does it work? Arch. Ital. Biol. 150, 91–106.
Seth, A.K., 2013. Interoceptive inference, emotion, and the embodied self. Trends Cogn. Sci. 17, 565–573, http://dx.doi.org/10.1016/j.tics.2013.09.007.
Shevrin, H., Panksepp, J., Brakel, L., Snodgrass, M., 2012. Subliminal affect valence words change conscious mood potency but not valence: is this evidence for unconscious valence affect? Brain Sci. 2, 504–522, http://dx.doi.org/10.3390/brainsci2040504.
Shewmon, D., Holmes, G., Byrne, P., 1999. Consciousness in congenitally decorticate children: developmental vegetative state as self-fulfilling prophecy. Dev. Med. Child Neurol. 41, 364–374.
Shimamura, A., 2000. The role of the prefrontal cortex in dynamic filtering. Psychobiology 28, 207–218, http://dx.doi.org/10.3758/BF03331979.
Shipko, S., 1982. Alexithymia and somatization. Psychother. Psychosom. 37, 193–201, http://dx.doi.org/10.1159/000287573.
Sigman, M., Dehaene, S., 2005. Parsing a cognitive task: a characterization of the mind's bottleneck. PLoS Biol. 3, e37, http://dx.doi.org/10.1371/journal.pbio.0030037.
Silvetti, M., Alexander, W., Verguts, T., Brown, J., 2014. From conflict management to reward-based decision making: actors and critics in primate medial frontal cortex. Neurosci. Biobehav. Rev 46 (Pt 1), 44–57, http://dx.doi.org/10.1016/j.neubiorev.2013.11.003.

Simmons, W., Hamann, S., Harenski, C., Hu, X., Barsalou, L., 2008. fMRI evidence for word association and situated simulation in conceptual processing. J. Physiol. Paris 102, 106–119, http://dx.doi.org/10.1016/j.jphysparis.2008.03.014.
Simons, D.J., Chabris, C.F., 1999. Gorillas in our midst: sustained inattentional blindness for dynamic events. Perception 28, 1059–1074.
Simons, D.J., Rensink, R.A., 2005. Change blindness: past, present, and future. Trends Cogn. Sci. 9, 16–20, http://dx.doi.org/10.1016/j.tics.2004.11.006, S1364-6613(04)00293-1[pii].
Smith, R., Lane, R., 2015. The neural basis of one's own conscious and unconscious emotional states. Neurosci. Biobehav. Rev. 57, 1–29.
Smith, R., Lane, R., 2016. Unconscious emotion: a cognitive neuroscientific perspective. Neurosci. Biobehav. Rev. 69, 216–238.
Smith, R., Braden, B., Chen, K., Ponce, F., Lane, R., Baxter, L., 2014. The neural basis of attaining conscious awareness of sad mood. Brain Imaging Behav., http://dx.doi.org/10.1007/s11682-014-9318-8.
Smith, R., 2016. The relationship between consciousness, understanding, and rationality. Philos. Psychol., 1–15 (accessed: 21.04.16.) http://dx.doi.org/10.1080/09515089.2016.1172700.
Smith, R., Alkozei, A., Lane, R., Killgore, W.D.S., (2016). Unwanted reminders: the effects of emotional memory suppression on subsequent neuro-cognitive processing. doi: 10.1016/j.concog.2016.07.008.
Solms, M., Panksepp, J., 2010. Why depression feels bad. In: Perry, E., Collerton, D., LeBeau, F., Ashton, H. (Eds.), New Horizons in the Neuroscience of Consciousness. John Benjamins Publishing Company, pp. 169–179.
Solms, M., Panksepp, J., 2012. The id knows more than the ego admits: neuropsychoanalytic and primal consciousness perspectives on the interface between affective and cognitive neuroscience. Brain Sci. 2, 147–175, http://dx.doi.org/10.3390/brainsci2020147.
Solms, M., Turnbull, O., 2002. The Brain and the Inner World: An Introduction to the Neuroscience of Subjective Experience. Karnac Books.
Solms, M., 2015. The Feeling Brain: Selected Papers on Neuropsychoanalysis. Karnac Books, London.
Solms, M., 2016. Consciousness by surprise: a neuropsychoanalytic approach to the hard problem. In: Poznanski, R., Tuszynski, J., Feinberg, T. (Eds.), Biophysics of Consciousness: A Foundational Approach. World Scientific, New York.
Sperli, F., Spinelli, L., Pollo, C., Seeck, M., 2006. Contralateral smile and laughter, but no mirth, induced by electrical stimulation of the cingulate cortex. Epilepsia 47, 440–443, http://dx.doi.org/10.1111/j.1528-1167.2006.00442.x.
Sreenivasan, K.K., Curtis, C.E., D'Esposito, M., 2014. Revisiting the role of persistent neural activity during working memory. Trends Cogn. Sci. 18, 82–89, http://dx.doi.org/10.1016/j.tics.2013.12.001.
Stefurak, T., Mikulis, D., Mayberg, H., Lang, A., Hevenor, S., Pahapill, P., Saint-Cyr, J., Lozano, A., 2003. Deep brain stimulation for Parkinson's disease dissociates mood and motor circuits: a functional MRI case study. Mov. Disord. 18, 1508–1516, http://dx.doi.org/10.1002/mds.10593.
Steiner, A., Redish, A., 2014. Behavioral and neurophysiological correlates of regret in rat decision-making on a neuroeconomic task. Nat. Neurosci. 17, 995–1002, http://dx.doi.org/10.1038/nn.3740.
Stonnington, C., Locke, D., Hsu, C.-H., Ritenbaugh, C., Lane, R., 2013. Somatization is associated with deficits in affective Theory of Mind. J. Psychosom. Res. 74, 479–485, http://dx.doi.org/10.1016/j.jpsychores.2013.04.004.
Striedter, G., 2005. Principles of Brain Evolution. Sinauer Associates, Sutherland, MA, MA.
Stutz, R., Rossi, R., Hastings, L., Brunner, R., 1974. Discriminability of intracranial stimuli: the role of anatomical connectedness. Physiol. Behav. 12, 69–73, http://dx.doi.org/10.1016/0031-9384(74)90069-9.
Sur, M., Rubenstein, J., 2005. Patterning and plasticity of the cerebral cortex. Science 310, 805–810, http://dx.doi.org/10.1126/science.1112070 (80-.).
Tamietto, M., de Gelder, B., 2010. Neural bases of the non-conscious perception of emotional signals. Nat. Rev. Neurosci. 11, 697–709, http://dx.doi.org/10.1038/nrn2889.
Taylor, G., Parker, J.D.A., Michael Bagby, R., Acklin, M.W., 1992. Alexithymia and somatic complaints in psychiatric out-patients. J. Psychosom. Res. 36, 417–424, http://dx.doi.org/10.1016/0022-3999(92)90002-J.
Thorndike, E., 1911. Animal Intelligence: Experimental Studies. Macmillan, New York, NY.
Tomer, R., Denes, A., Tessmar-Raible, K., Arendt, D., 2010. Profiling by image registration reveals common origin of annelid mushroom bodies and vertebrate pallium. Cell 142, 800–809, http://dx.doi.org/10.1016/j.cell.2010.07.043.
Tononi, G., Koch, C., 2015. Consciousness: here, there and everywhere? Philos. Trans. R. Soc. Lond. B. Biol. Sci. 370, 200–227, http://dx.doi.org/10.1098/rstb.2014.0167.
Tovote, P., Fadok, J., Lüthi, A., 2015. Neuronal circuits for fear and anxiety. Nat. Rev. Neurosci. 16, 317–331, http://dx.doi.org/10.1038/nrn3945.
Trowill, J., Panksepp, J., Gandelman, R., 1969. An incentive model of rewarding brain stimulation. Psychol. Rev. 76, 264–281.
Urban, D., Roth, B., 2015. DREADDs (designer receptors exclusively activated by designer drugs): chemogenetic tools with therapeutic utility. Annu. Rev. Pharmacol. Toxicol. 55, 399–417.
Valenstein, E., 1966. The anatomical locus of reinforcement. In: Stellar, E., Sprague, J. (Eds.), Progress in Physiological Psychology, Vol. 1. Academic Press, New York, pp. 149–190.
Watt, D., Panksepp, J., 2009. Depression: an evolutionarily conserved mechanism to terminate separation distress? a review of aminergic, peptidergic, and neural network perspectives. Neuropsychoanalysis 11, 7–51, http://dx.doi.org/10.1080/15294145.2009.10773593.
Watt, D., Pincus, D., 2004. Neural substrates of consciousness: implications for clinical psychiatry. In: Panksepp, J. (Ed.), Textbook of Biological Psychiatry. Wiley, Hoboken, NJ, pp. 75–110.
Waugh, C., Lemus, M., Gotlib, I., 2014. The role of the medial frontal cortex in the maintenance of emotional states. Soc. Cogn. Affect. Neurosci. 9, 2001–2009, http://dx.doi.org/10.1093/scan/nsu011.
Weiskrantz, L., 2009. Blindsight: A Case Study Spanning 35 Years and New Developments, [2nd Ed, Oxford Psychology Series. Oxford University Press, Oxford, New York.
Whalen, P., Kagan, J., Cook, R., Davis, F., Kim, H., Polis, S., McLaren, D., Somerville, L., McLean, A., Maxwell, J., Johnstone, T., 2004. Human amygdala responsivity to masked fearful eye whites. Science 306, 2061, http://dx.doi.org/10.1126/science.1103617 (80-.).
Wilson-Mendenhall, C., Barrett, L., Simmons, W., Barsalou, L., 2011. Grounding emotion in situated conceptualization. Neuropsychologia 49, 1105–1127, http://dx.doi.org/10.1016/j.neuropsychologia.2010.12.032.
Winawer, J., Witthoft, N., Frank, M.C., Wu, L., Wade, A.R., Boroditsky, L., 2007. Russian blues reveal effects of language on color discrimination. Proc. Natl. Acad. Sci. U. S. A. 104, 7780–7785, http://dx.doi.org/10.1073/pnas.0701644104.
Winkielman, P., Berridge, K., 2004. Unconscious emotion. Curr. Dir. Psychol. Sci. 13, 120–123, http://dx.doi.org/10.1111/j.0963-7214.2004.00288.x.
Winkielman, P., Berridge, K., Wilbarger, J., 2005. Unconscious affective reactions to masked happy versus angry faces influence consumption behavior and judgments of value. Pers. Soc. Psychol. Bull. 31, 121–135, http://dx.doi.org/10.1177/0146167204271309.
Winn, P., Tarbuck, A., Dunnett, S., 1984. Ibotenic acid lesions of the lateral hypothalamus: comparison with the electrolytic lesion syndrome. Neuroscience 12, 225–240, http://dx.doi.org/10.1016/0306-4522(84)90149-0.
Womelsdorf, T., Fries, P., 2007. The role of neuronal synchronization in selective attention. Curr. Opin. Neurobiol. 17, 154–160, http://dx.doi.org/10.1016/j.conb.2007.02.002.
Wright, J., Panksepp, J., 2012. An evolutionary framework to understand foraging, wanting, and desire: the neuropsychology of the SEEKING System. Neuropsychoanalysis 14, 5–39.
Xin, F., Lei, X., 2015. Competition between frontoparietal control and default networks supports social working memory and empathy. Soc. Cogn. Affect. Neurosci. 10, 1144–1152, http://dx.doi.org/10.1093/scan/nsu160.
Yeo, B., Krienen, F., Sepulcre, J., Sabuncu, M., Lashkari, D., Hollinshead, M., Roffman, J., Smoller, J., Zöllei, L., Polimeni, J., Fischl, B., Liu, H., Buckner, R., 2011. The organization of the human cerebral cortex estimated by intrinsic functional connectivity. J. Neurophysiol. 106, 1125–1165, http://dx.doi.org/10.1152/jn.00338.2011.
Yovell, Y., Bar, G., Mashiah, M., Baruch, Y., Briskman, I., Asherov, J., Lotan, A., Rigbi, A., Panksepp, J., 2016. Ultra-low-dose buprenorphine as a time-limited treatment for severe suicidal ideation: a randomized controlled trial. Am. J. Psychiatry 173, 491–498, http://dx.doi.org/10.1176/appi.ajp.2015.15040535.
Zellner, M., Watt, D., 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, http://dx.doi.org/10.1016/j.neubiorev.2011.01.003.
Zubieta, J., Ketter, T., Bueller, J., Xu, Y., Kilbourn, M., Young, E., Koeppe, R., 2003. Regulation of human affective responses by anterior cingulate and limbic mu-opioid neurotransmission. Arch. Gen. Psychiatry 60, 1145–1153, http://dx.doi.org/10.1001/archpsyc.60.11.1145.
Zylberberg, A., Dehaene, S., Roelfsema, P., Sigman, M., 2011. The human Turing machine: a neural framework for mental programs. Trends Cogn. Sci. 15, 293–300, http://dx.doi.org/10.1016/j.tics.2011.05.007.
Zylberberg, A., Fernández Slezak, D., Roelfsema, P., Dehaene, S., Sigman, M., 2010. The brain's router: a cortical network model of serial processing in the primate brain. PLoS Comput. Biol. 6, e1000765, http://dx.doi.org/10.1371/journal.pcbi.1000765.