ARTICLE

Relational and affective neuroscience: a quiet revolution in psychiatric and psychotherapeutic practice

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SUMMARY

We consider some advances in relational and affective neuroscience and related disciplines that attempt to resolve some fundamental aspects of the mind–brain problem. We consider the key role of affect in generating consciousness and in meeting our essential survival needs; the neural correlates of relating; how self and other are represented in the brain and awareness of self and other is generated through interoceptive predictive processes. We describe some leading models of the generation and purpose of consciousness, linking theories of affective and cognitive consciousness. We discuss psychiatric and psychotherapeutic innovations arising from this research, new integrated biopsychosocial interventions and the obstacles to be overcome in applying these models in practice.

LEARNING OBJECTIVES

After reading this article you will be able to:

- understand Panksepp's basic emotion command systems as the basis of affective consciousness and evolutionarily endowed affectively driven behaviour
- explain theories of brain function such as the Bayesian brain, free energy principle, interoception, exteroception and embodied mentalisation and their relationship to consciousness
- comprehend the relevance of affective and relational neuroscience for psychiatry and the psychotherapies.

KEYWORDS

Affective and relational neuroscience; emotion command systems; prediction error; interoception; psychoanalysis.

The neuroscientific understanding of emotion and relating has lagged behind that of cognition and behaviour. In part this is a consequence of the complexity of the subject and the difficulty in finding objective measures for subjective aspects of mental life. In recent years there have been significant developments that allow observations of brain and mind function to be correlated. In this way psychological theories can be empirically cross-referenced with neuroscientific hypotheses. This has given rise to interdisciplinary dialogue and innovation.

It is impossible to do justice here to the range of neuroscience research in this area. We attempt to describe a growing consensus in key areas that have an impact on our understanding of human experience and inform clinical work.

We hope to make clear that interdisciplinary thinking across the biological–psychological divide permits a critical review, reworking and refining of key psychological concepts such as Freudian metapsychology. Resultant modifications of therapeutic technique will potentially lead to novel approaches and hopefully improve outcomes for patients. They may also inform biological hypotheses, with resultant psychopharmacological innovation and the development of fully integrated biopsychosocial models with corresponding integrated biological and psychological treatments.

In this article we review the work of several authors: Panksepp in delineating the basic mammalian affective systems; Damasio in studying the processes underlying consciousness; Friston in hypothesising a predictive model of perception and action; Fotopoulou & Tsakiris in linking interoception and exteroception with development of self; Solms in integrating neuroscience with Freudian theory. We will describe these under four linked and overlapping headings of Affect, Self and other, Awareness, Interoception and Embodied Mentalisation, and Consciousness. We will touch on how these developments inform the burgeoning literature on the neuroscience of attachment, a subject that deserves an article in its own right. We will use a fictitious clinical vignette to illustrate the clinical relevance of the neuroscience findings in each area.

Affect: linking biological, psychological and social psychiatry

Clinical vignette: Miss A

Miss A presented with mood instability and hypomanic episodes in late adolescence and her early 20s. Some were associated with stimulant misuse. During the week following the birth of her first child she became convinced that her baby was seriously ill and sought urgent medical attention. Attempting to get a lift to the hospital she ran out into the road with her baby to stop a car. She was found to be hypomanic and was detained under the Mental Health Act 1983. She denied recent stimulant use. Subsequently during psychotherapy, she described difficulties separating from her mother to attend school in early childhood, being afraid that if she was left her mother would not return to pick her up. Curiously, as an adult she complained of transient amotivational states in which she was unable to move. To emerge from these states she would look at pornographic literature or take stimulants, which often led to manic episodes.

Until recently neuroscience research focused on cognition and behaviour, on the basis that these could be observed objectively and so could be studied through empirical scientific methods. Perception, attention, memory and, to an extent, attachment behaviour could be explored using these methods, but not emotion, which was considered subjective. One consequence of the discovery of the biological basis of emotion (affect) in the brain has been the emergence of a new field of research in affective neuroscience.

Before affective neuroscience emerged, many theories of emotion and classifications had been proposed. One of the earliest, the James–Lange theory (after James 1884), proposed that physiological arousal itself gave rise to the emotional experience of fear. The Cannon–Bard theory (after Cannon 1927) countered this, proposing that physiological and emotional arousal are triggered simultaneously and independently. Fridlund (1987) studied the non-verbal communication of emotion, describing six universal basic emotions based on observations of facial expressions, the physiological response to emotion and ethnographic studies. Tomkins (1962, 1963) identified nine primary affects, identified by intensity and physiological expression, including shame and disgust.

These accounts are based on studies of the expression of emotion. Studies of the biological basis of emotion are a more recent development. LeDoux (1996) studied fear conditioning, identifying two pathways to the amygdala. The fast, subcortical pathway mediated rapid behavioural responses to threats (Pavlovian threat conditioning). The slow pathway provided highly processed cortical information responsible for the feeling of fear. His research on memory storage of fear responses furthered understanding of the way in which exposure therapy reduces threat reactions, leading to a new therapeutic understanding of post-traumatic stress. His proposal was that the brain detects feelings but does not create them.

Panksepp and affective neuroscience

Panksepp (1998) coined the term affective neuroscience. He undertook his primary research in mammals, discovering seven anatomically and functionally distinct subcortical basic (primary-process) emotion command systems, each with their own neurochemistry. These systems, usually identified by capitalising their names, are SEEKING, PANIC, FEAR, RAGE, LUST, CARE and rough and tumble PLAY. They exist across all mammalian species.

The seven systems mediate what is called core affective consciousness, consciousness arising from awareness of the homeostatic status of the interior of the body and autonomic nervous system (interoception). They also provide information about the state of the bodily self in relation to the external world, mediating stereotypical actions to meet inner homeostatic and survival needs. Core affective consciousness is both quantitative, determining wakefulness, and qualitative, providing information in broad categories of both pleasure and unpleasure. A specific qualitative awareness is associated with each individual emotion command system and individual systems motivate the organism towards specific categories of behaviour. For example, with reference to the PANIC system:

- unpleasure equates to separation distress (mental pain and anxiety), which mediates proximity-seeking behaviour
- pleasure equates to the comfort of social proximity.

Core affective consciousness itself being grounded in awareness of the interior of the body originates in the interoceptive body map, represented in deep brain regions including the hypothalamus, ventral tegmental area, parabrachial nuclei, locus ceruleus, reticular formation and periaqueductal grey (PAG). In contrast the external world, perceived through exteroceptive senses, is represented in body maps on the cortical surface. Consciousness of the external world is modality specific, whereas affective consciousness is a ‘state dependent’ function perceiving both the state of the interior of the body and the response of the individual to external events. In this sense, core affective consciousness is the basis of subjectivity (Fig. 1).

The patterns of behaviour mediated by the emotion command systems are not learned. These

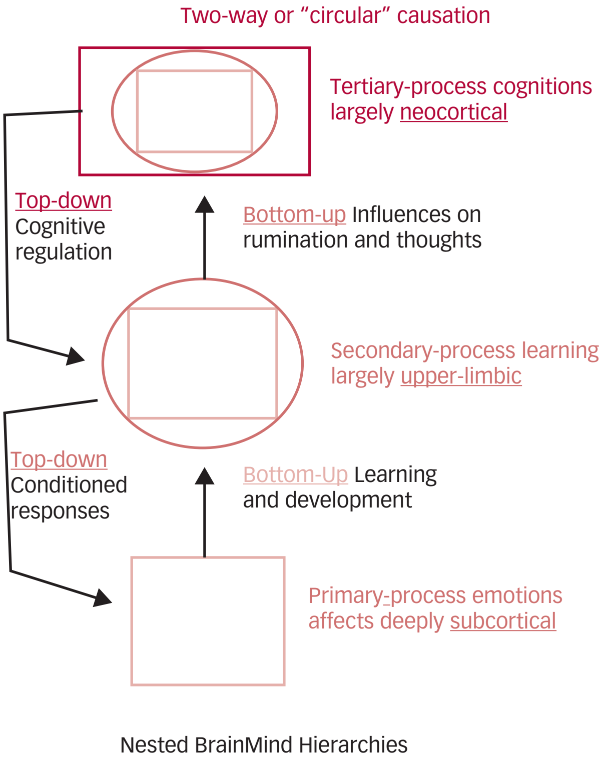

FIG 1 Panksepp's nested brain–mind hierarchies, illustrating bottom-up cognisation of affect and top-down affect regulation (Panksepp 2014).

deep brain processes are not directly open to modulation by environmental influence but are subject to top-down cortical control. For example, the SEEKING system mediates appetitive foraging behaviour. Once an animal has learned which objects in the environment satisfy the appetitive drive this information is laid down cortically, informing future foraging without modifying the SEEKING system itself.

As examples, the anatomy, neurochemistry and function of the SEEKING, PANIC, FEAR and RAGE systems are outlined in Table 1.

The implications of Panksepp's model

Panksepp's discovery not only demonstrated that affect and affective consciousness are generated in the brain but provided a scientific basis for the objective study of emotion. The implications are far reaching. Developing new psychopharmacological agents has depended on animal models. Indirect measures such as the forced swim test, tail suspension test or shock avoidance are proxy measures for depression in rodents. The reliable identification of the neural pathways underpinning separation distress, with their corresponding neurochemistry, offer a means of directly measuring the activity of the PANIC system in response to antidepressant agents. The possibility of direct manipulation of emotion command systems to treat mental disorders has resulted in a number of psychiatric innovations. It is beyond the remit of this article to undertake a critical evaluation of these studies but they indicate promising areas for development.

There are implications for cognitive neuroscience research too, where studies of 'emotional salience' commonly confine themselves to the study of the axis between the dorsolateral prefrontal cortex (cognition and executive function) and the amygdala. It is clear that the amygdala is responsible for threat detection and evaluating pleasant and unpleasant emotional experiences but is not the prime mover in other basic emotions. Omitting the other emotion command systems from our understanding of the interaction between cognition and emotion limits the accuracy of our psychological models.

The discovery of the emotion command systems can inform and update our traditional psychological theories. For example, Freud (1905) described libido as an object seeking drive blind to its object. The SEEKING system seems the closest neural approximation to this psychoanalytic concept. On this basis, falsifiable neuroscientific models of psychoanalytic concepts are being developed permitting the scientific investigation of Freud's metapsychology and a reintroduction of psychoanalysis into scientific discourse.

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TABLE 1 Anatomy, neurochemistry and function of four of the seven basic emotion command systems

System	Anatomy	Neurotransmitters	Function
SEEKING	Mesolimbic/mesocortical pathway, PAG, lateral hypothalamus, nucleus accumbens, ventral tegmental area	Dopamine, including descending glutaminergic components Opioids Neuropeptides, e.g. neurotensin and orexin	Behavioural: energetic exploration to locate resources to satisfy appetite (hunger, thirst or sexual appetite). Psychological: motivates interest, curiosity, sensation-seeking and the search for higher meaning. It makes sense of contingencies, cements the connection between cause and effect in the world, thereby creating ideas
PANIC	PAG, BNST, pre-optic area, dorsomedial thalamus. The anterior cingulate gyrus in higher species	Opioids, oxytocin, prolactin Inhibitory CRF Glutamate	Behavioural: separation distress circuits – their activity promotes bonding and proximity-seeking behaviour in young mammals and social behaviour in adults. Psychological: the psychological pain and panic/anxiety of separation
FEAR	Dorsal PAG, medial hypothalamus, central and lateral amygdala	GABA Diazepam-binding inhibitor Peptide hormones, e.g. CRF, cholecystokinin, α-MSH Neuropeptide Y	Behavioural: unconditioned fear response to competitors/predators; fight or flight. Psychological: anxiety from external threat.
RAGE	PAG, BNST, medial hypothalamus, medial amygdala	Substance P (key modulator) GABA and ACh.	Behavioural, in three distinct aggressive circuits: (a) affective attack – enraged = fight or flight; (b) predatory aggression linked to SEEKING; (c) intermale aggression (testosterone related). Psychological: anger stimulated by restriction of freedom, irritation to body surfaces or obstructed access to resources

PAG, periaqueductal grey; BNST, bed nucleus of the stria terminalis; CRF, corticotropin-releasing factor; GABA, gamma-aminobutyric acid; α-MSH, α-melanocyte-stimulating hormone; ACh, acetylcholine.

The emotion command systems provide a direct link between brain chemistries, behavioural responses and the subjective experience of emotion. It is self-evident that each emotion requires an object for satisfaction of the need. The emotion command systems are therefore fundamentally relational and social, providing a biological model for the drive to intimate and social relating. The applications to clinical practice become clear if we return to the clinical vignette and Miss A.

Self and other: the drive to relate

Clinical vignette: An affective neuroscience formulation for Miss A

Miss A described an insecure attachment, being anxious about separations from early childhood. In the absence of higher-level representations to regulate her affective states, her PANIC system was readily activated by separations. In the puerperium, biological and psychological events coincided. Falling oxytocin levels (a neurotransmitter in the PANIC system) increased her PANIC-mediated biological vulnerability. The puerperium also represented a psychological separation between mother and baby. This triggered a psychological defence. Her survival anxiety was projected into her baby, generating intense separation anxiety and the need to find a doctor (caregiver). Further to this, in psychodynamic terms mania is a defence against depression (separation distress). Mania arises through activation of the dopaminergic SEEKING system, exchanging the distress of separation for the thrill of discovering the new. In her manic state, Miss A's reality testing is impaired and she attempts to convey her projected infantile self to the hospital representing mother to ensure its survival. Later in therapy, she describes amotivational states. Watt & Panksepp (2009) described how severe continued separation distress 'switches off' SEEKING (mediated by dynorphin or corticotropin-releasing factor), SEEKING being the motivational drive. Miss A tries to address this by activating desire (looking at pornography) or self-medicating with dopamine agonists.

The PANIC system can be considered the biological substrate for the drive to relate. Panksepp proposed that the PANIC system ensures the survival of young mammals while their attachments and survival skills are developing. Bowlby proposed a similar early imprinting process in humans, present before the development of maternal attachment at 6–8 months. Alongside other inborn reflexes, such as the rooting reflex, orientation towards maternal smell and to faces, the PANIC system is responsible for the emotional salience of babies' interactions with their parents. This drive to relate is referred to in the attachment literature, along with a specialised system in humans for predicting and inferring the mental state of others, which leads to the development of theory of mind, mentalisation and affect regulation (Fonagy 2004).

The PANIC system, in conjunction with PLAY, promotes social relating between peers, mediating the pleasure of relating and the pain of social exclusion. As such, PANIC promotes group and social behaviour. Social exclusion of individuals or minorities is associated with separation distress and vulnerability to depression and anxiety. This is relevant to social scientists and group therapists. The fear of social exclusion may be a prime motivator towards social attachments and conforming to conscious and unconscious group behaviour, even when doing so opposes the individual's rational beliefs.

The representation of self and other in the brain

Damasio (1999) described hierarchical neural structures for the representation of self and other and the generation of consciousness. He considered the representation of, and interaction between, self and other and consciousness to be indivisible from one another. The most basic representation of the 'proto-self' is a collection of neural patterns monitoring the internal state of the body as it responds to the environment in the periaqueductal grey, hypothalamus and insula (Parvizi 2001; Northoff 2004). More sophisticated representations progressing through the limbic system give rise to emotions reaching conscious awareness. Finally, at the highest level the autobiographical self moves beyond the here and now and is reliant on representations of self and other in declarative memory systems.

In cortical regions, self and other are represented in two large-scale neural networks, one lateral, the other medial (Uddin 2007). The lateral frontoparietal network and its associated mirror neuron areas are thought to bridge the gap between bodily self and others in the here and now. This is achieved through the action of mirror neurons which fire when an action is performed by the self or observed in another (Rizzolatti 1996). These neurons respond to prosody in social interactions, allowing motor simulations in the person, from which the emotional state of the other is inferred. The medial network is referred to as the default mode network. This is active when executive functions are offline. It appears to transact processes which are termed 'task-unrelated imagery and thought' processing information about self and other in evaluative terms after the event.

Evidence suggests that the right lateral frontoparietal network undergoes a critical period of development during the second year of life (Schore 1994). Optimal development of this region is dependent on attuned, contingent relating with attachment figures. Absence of this relational environment may lead to impaired dendritic branching and apoptosis, with consequent diminution in cortical volume (Schore 1997). Feldman (2011) demonstrated that the limbic systems of mothers and infants measured by blood oxytocin levels are synchronised during play. It is proposed that mirror neuron systems link maternal and infant limbic systems, with significant implications for emotional and neural development.

The scientific literature outlining the development of the capacity for mentalisation identifies the capacity for self-reflection as having a central role in affect regulation. It appears that the lateral fronto-parietal network operates on the basis of identification between self and other. The default mode network, particularly the temporoparietal junction, interpolates an inhibition of identification, which is key to perspective-taking and the development of a capacity for self-reflection (Fonagy 2009). This capacity for reflecting on as well as experiencing the emotions of self and other have a critical influence on the capacity for representation, abstraction and symbolisation.

Self, other and symbolisation

Clinical vignette: Mr B

Mr B's mother contracted rubella during pregnancy. Mr B was born with congenital blindness but no other disorder. During Mr B's infancy, his mother was attentive and attuned, responding to her son's cues and distress, but B was unable to see his mother's facial expressions and so could not engage in face-to-face interaction. At the age of 5, B was noted to have marked difficulties in social relationships. He could not engage in pretend play. On psychological testing he was found to have developmental deficits suggestive of autism, including limited capacity for abstract thinking and the semantic use of language, although his emotional expression and ability to make emotional contact were relatively spared. A programme was developed for him using touch, emotional expression and active guidance to promote interpersonal relating. Over time his autistic symptoms lessened as he found other routes aside from the visual one to understanding that other people relate in different ways to a shared world (Hobson 1999).

Studies of infant development confirm that, in the first instance, babies are egocentric, assuming that the world is as they see it from their own perspective. The term 'egocentric' used here does not imply the development of an 'ego' as such at this early stage of development, but refers to the position from which the infant understands the physical and relational environment. When development during the first year of life progresses well, infants engage in prosodic face-to-face and embodied interaction with others. This is a prerequisite for the developmental progression of secondary intersubjectivity,

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in which the baby realises that theirs is not the only perspective on the world and that others have a perspective of their own (Trevarthen 1978). From this point on, babies demonstrate the ability to move back and forth between their own and another's perspective, a first step in the development of theory of mind. This ability appears to be a nodal step in subsequent development of the capacity for symbolic play, symbolic use of language and, ultimately, abstract thinking (Hobson 2002). Failure of these key developmental stages may have an impact on future mentalisation and the development of the capacity to express emotions symbolically through language, leading to alexithymia. This is a common finding in many mental disorders, including personality disorder, eating disorders and autism spectrum disorder.

A neurobiological account of autism spectrum disorder was proposed by Panksepp in the form of an opiate excess theory (Panksepp 1979). He suggested that 'neurotypical' individuals have a relative deficit of opiates in their PANIC system, so the absence of social contact is painful. While acknowledging the heterogeneity of autistic presentations, he proposed that in autism spectrum disorder opiate receptors in the PANIC system are saturated. As a result, social engagement is not emotionally salient because isolation is not sufficiently distressing to promote engagement with others. The developmental implication of this is that from birth infants who go on to develop autism spectrum disorder do not seek out social engagement, resulting in a series of negative outcomes in the development of language, abstract thinking and symbolisation. The implication of this is that the development of that cluster of deficits, which attract the diagnosis of autism, arises from disordered neurobiological mechanisms for relating and/or deficits or disorders in relating itself, the PANIC system being the driver for the neurotypical developmental trajectory. The combination of biological and relational contributions to the autism syndrome is illustrated in the case of Miss B, in whom the development of symbolic function is impaired not because motivation for engagement is lacking but because the sensory input required for face-to-face engagement in the relational world is absent.

Awareness, interoception and embodied mentalisation

In a recent paper Fotopoulou & Tsakiris (2017), following the Fristonian model, link the development of the minimal embodied self with early proximal embodied interactions with caregivers. As described above, interoception is thought to play a central role in self-awareness (Damasio 1994). In free energy terms (see below) subjective feeling states arise from inferences about the causes of interoceptive signals (Barrett 2015).

Fotopoulou & Tsakiris argue that the dependency of early infancy engenders a homeostatic necessity for embodied interactions with caregivers. These interactions inform the mentalisation process and thus the constitution of the minimal self, including the increasing sophistication of mental distinctions between subject–object, self–other and even pleasure–pain. Fotopoulou (2015) proposed that the progressive integration and organisation of sensory and motor signals constitute the foundations of the minimal self, a process that can be understood from the point of view of psychology as 'embodied mentalisation', the ongoing dynamic process of maintaining and updating generative models from inside the body itself and these other bodies.

Fotopoulou & Tsakiris make the case that the progressive mentalisation of the affective core of selfhood does not take place through processes within the singular infant, but is mediated by the actions of caregivers, which bring about physiological changes, shaping current and future perception of bodily satisfaction, relief, pleasure, pain, etc. Further, they argue that correct identification of the origin of bodily and mental states is necessary not just for self–other distinction but also for social relatedness and cognition.

In conclusion, interoceptive awareness is important for emotional awareness and mental well-being. Conversely, and put simply, psychological elements of mental disorder may be the result of an inability to reduce interoceptive prediction errors.

Consciousness

How consciousness arises remains a hotly debated philosophical question. Arguments centre on the so-called 'easy' question and the 'hard' question (Chalmers 1995). The easy question – 'What are the neural structures responsible for generating consciousness?' – is in fact hard enough to answer. The hard question concerns how information processing in the brain becomes subjective experience, how matter becomes feeling or, as Dennett (1981) puts it, 'every mental state is (identical with) a physical event in the brain' (p. xxvii). Most neuroscientific research concerns the easy question.

Differing philosophical approaches to the mind–brain problem have been proposed, for example materialist, idealist, monist and dualist. The position taken in this article is termed dual-aspect monism, i.e. we are made of one type of stuff, but that stuff can be experienced in two different ways – objectively as matter (brain) and subjectively as experience (mind).

We have known since the 1950s that consciousness arises in the reticular (ascending) activating system in the brain-stem and not, as Freud thought, in the cortex. Consciousness is therefore an endogenous property of the brain. However, it is now widely accepted that brain activity is predominantly unconscious. Conscious working memory (short-term memory) is a limited resource comprising on average only seven items. There is therefore continuous pressure to consolidate autobiographical declarative memories to long-term memory stores and to automatise procedural memories, for example by learning a behavioural procedure. Freud termed this automatisation 'consolidation'. It is worth pointing out that unconscious mental activity is not the same as Freud's repressed or dynamic unconscious.

There have been some new developments in the neuroscientific understanding of consciousness in recent years. Karl Friston's prediction error and free energy principle have made an important contribution to the current debate.

The Bayesian brain, prediction error, free energy

Friston's theory is based on Bayes' mathematical theorem, which describes how the probabilities assigned to a hypothesis are updated in the light of new evidence. The theorem provides a mathematical model for the way existing (prior) beliefs about what is about to happen (predictions) sample new sensory data to update those beliefs, generating new predictions (posterior beliefs). Friston applied Bayes' theorem to brain function.

The concept of the Bayesian brain defines humans as biological self-organising agents. The biological imperative is to maintain homeostasis and, to do this, the organism needs to occupy a limited repertoire of sensory states. This biological imperative is met by sensory, emotional, cognitive and motor systems making predictions about the state of the interior of the body and the external world. Based on this, the free energy principle (Friston 2010) proposes that our brains run an internal model of the causal order of world that continually creates predictions about what we expect to perceive. These predictions are then matched with what we actually perceive, and the divergence between predicted sensory data and actual sensory data yields a prediction error. We feel 'surprise' or unpredictability. These generative models are constantly updated to reduce representational errors and minimise the risk of 'surprise' by minimising free energy. In this model, consciousness arises as a consequence of prediction error directing attention to the error to update the generative model. Mathematically speaking, if the model were to fit external reality perfectly, consciousness would not be necessary.

The internal prediction error model is hierarchical, comprising higher and lower processing layers. Lower levels process simple data such as sensory stimuli, affects and motor commands, while higher levels process categorisations such as object recognition and action selection. The highest levels process mental states such as mental imagery, emotional experience, conscious goals, planning and reasoning.

The minimisation of free energy is also value laden (Clark 2013). It is proposed that we value such qualities as truth, honesty, authenticity, simplicity and wisdom because they allow us to develop beliefs about the world and equip us with relatively reliable 'hyperpriors', which allow us to make accurate predictions.

This seems relatively straightforward if we consider sensory experience. Perhaps less obviously, the same applies to feelings in relationships in which the vast majority of our interactions are based on prior beliefs that are, for the most part, unconscious. These beliefs, relational prediction models learned from experience and based on long-term and procedural memory, could be what we term transference. However, making emotional predictions about relationships is highly nuanced along many variables of human interaction. Transference predictions can be extremely unreliable, leading to all manner of dysfunctional relating.

Holmes (2020: p166), while acknowledging that Friston's model has not achieved universal agreement, summarises the potential impact it may have on the psychotherapies:

> 'If psychological health is associated with binding free energy and minimising prediction error, then procedures which foster these will be likely to be helpful, whatever their espoused brand name. These include: liberating agency; enhancing sensory sampling whether through CBT "experiments" or psychoanalytic free association; widening the range of possible top-down hypotheses through dream analysis and interpretation and the "active imagination"; fostering change-precipitating sadness; and modifying priors in the light of experience.'

As described above, Damasio too describes a hierarchical structure in the brain for the generation of consciousness (Damasio 1999). He distinguishes the contents of consciousness from the state of consciousness. The contents of consciousness (qualia) are derived from external perceptual mechanisms in response to the outside world. The state of consciousness is a product of the ascending activating system of the brain-stem, which monitors the internal state of the body. This state of consciousness represents the most basic embodiment of self in the present moment, i.e. 'the feeling of being ourselves in the world right now'. This is the most basic

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form of consciousness – the 'protoself'. The more sophisticated representations in the upper limbic system described above give rise to feelings that reach conscious awareness, which Damasio termed core consciousness. At the highest level, the autobiographical self is associated with extended consciousness or the state of 'consciousness of consciousness'.

The dynamic unconscious and defence mechanisms

These models of consciousness make an important distinction between affective consciousness and cognitive consciousness. Solms's account, expounded in Solms & Turnbull, (2002) account combines these into a single model. His hypothesis, following Panksepp, is that consciousness is affective. The human infant is not a blank slate. We are born with a set of innate needs, which are felt as affects (emotion command systems). Following Damasio and Friston, the main task of mental development is to learn how to meet these needs through optimising predictions. Innate predictions (priors) have to be reconciled with experience. Affects lead to behavioural tendencies, which consist of hard-wired predictions. These action tendencies are hereditary tools for survival, designed to meet our biological needs. In this model, consciousness enables us to learn from experience.

Solms argues that emotional needs are dealt with by the brain in the same way as procedural tasks such as learning to play the violin. We learn the best way of solving the problem and then automatise it, at which point it becomes unconscious. Automatisation utilises pathways in the subcortical structures of the basal ganglia and cerebellum. However, emotional tasks are not as straightforward as procedural ones and therefore the predictions we make which are automatised do not fully meet the particular emotional need they are designed for, the emotional conflicts we cannot resolve, such as the Oedipal dilemma. This results in a greater likelihood of unsuccessful, premature or 'illegitimate' predictions. Successful predictions are synonymous with successful affect regulation, i.e. along the pleasure–unpleasure continuum where unsuccessful predictions leave needs unmet.

Solms considers the process of automatising predictions to be the process Freud called repression. Freud thought that the aim of psychoanalysis was to return the repressed to consciousness, where it could be reworked in the service of finding a more adaptive solution. Solms here disagrees with Freud. He proposes that the repressed can never return to consciousness. However, when automatised predictions do not meet the emotional need, the failure to do so leads to a continued felt demand to meet that need. That feeling is experienced consciously and its impact can be observed through repeated maladaptive relating – transference. This allows for reworking of the need to find a more adaptive prediction, which can be automatised alongside the original prediction. This entails the affect being thought about, i.e. becoming conscious in working memory. As Solms points out, this is closely similar to Freud's (1920) original description (to paraphrase) that a memory trace arises instead of consciousness (consolidation) and consciousness arises instead of a memory trace (reconsolidation).

In summary, the cognitive unconscious is based on automatisation of successful predictions and the dynamic unconscious is based on premature automatisation of partially or unsuccessful predictions. The presence of feelings arising from these premature automatisations, if not resolved, requires secondary defences in addition to the primary repression. Solms here separates repression from other forms of defence, placing it as the primary mechanism for achieving emotional and psychological homeostasis.

Examples of the feeling derivatives of premature predictions are panic related to a fear of losing an emotional attachment or rage resulting from frustration at basic emotional needs not being met These can form the basis for emotional and mental disorders.

Solms's formulation of mental states, based on Panksepp and Friston, adds another layer from which to understand the problem a patient is bringing. It becomes possible to formulate a problem in terms of which of the emotion command systems is involved and the prediction arising from it.

Clinical vignette: Ms C

Ms C is a young woman with a diagnosis of bipolar disorder. There is a family history of psychosis. At different times she exhibits compulsive sexual behaviours and obsessive–compulsive features. She remains dependent on her parents and has not left home since returning from graduating at university 10 years ago, except for one brief period. On that occasion she experienced an unbearable sense of loneliness. Early attempts at work foundered in not being able to assert herself appropriately, especially with authority figures. Recently, after a serious suicide attempt, she worked effectively as a healthcare assistant and made plans to train as a children's nurse. This broke down when she developed a false belief that she was a paedophile.

At different times it has been possible to implicate failures to meet her emotional needs associated with all the emotion command systems, for example PANIC in her dependency, LUST in her sexually compulsive behaviours, RAGE in her inability to express appropriate anger – all familiar themes in psychotherapy. However, the central difficulty that underlies all her difficulties appears to be a failure to

PLAY. She is unwilling to engage with the outside world and test herself in the rough and tumble of ordinary life. When she does so, she becomes overwhelmed with anxieties, which lead her to retreat into the perceived safety of dependency.

A central problem for the therapist was his repeated frustration that whatever he attempted to work on, Ms C rapidly shifted ground to a different set of emotional problems. The understanding of a failure to PLAY as a central drive underlying her rapidly changing mental states made sense of this countertransference as the patient being unable to maintain emotional engagement with the therapist, which when allowed led inevitably to an increased sense of dependency, followed by a reaction to escape from it. This allowed the therapist to maintain a clearer focus in being able to interpret whatever was current within the context of the central difficulty. The emotion command systems model added another perspective to the psychoanalytic understanding, thereby contextualising the psychoanalytic problems in frustrated basic emotional needs. This has an added element in removing possible unwanted value judgements in the analysis of problem behaviours.

There have been a number of hypotheses linking brain studies with the psychoanalytic theory of defence mechanisms. Northoff & Boeker (2006) make preliminary hypotheses that particular principles of neuronal integration may be related to specific defence mechanisms. For example, displacement may be related to an inability to use attention to reverse signal changes, leading to abnormal modulation; somatisation may be accounted for at least partially by abnormal functional balance between top-down and bottom-up modulation across medial cortical and subcortical regions. Introjection is hypothesised to be related to abnormal reciprocal modulation and attenuation of neural activity in medial and lateral prefrontal cortex during emotional–cognitive interaction; sensorimotor regression corresponds to abnormal modulation of functional unity across medial prefrontal cortical regions. They conclude that these hypotheses provide a starting point for future empirical testing of psychophysiological mechanisms underlying defence mechanisms.

Dreaming: a controversial issue

When rapid eye movement (REM) sleep was found to be associated with ponto-geniculo-occipital (PGO) waves an assumption was made that REM sleep was synonymous with dreaming. Dreaming was considered a meaningless epiphenomenon undermining Freud's psychological concept of dreams in favour of physiological theories (Hobson 1977).

Solms (1995) undertook a study of 332 neurological and neurosurgical patients with brain lesions. He used Luria's method of syndrome analysis to investigate the components of the functional system supporting dreaming. He demonstrated that the essential psychological processes of dreaming are mediated by higher forebrain structures rather than the primitive brain-stem nuclei that regulate REM sleep. Of the 61 patients with brain-stem lesions, none demonstrated cessation of dreaming. Total cessation of dreaming was found in lesions affecting the inferior parietal and bilateral mediobasal frontal lobes in particular. Three factors mediated by the inferior parietal and bilateral mediobasal frontal lobes emerged as being essential to the conscious experience of dreams: (a) symbolic operations, (b) spatial thought and (c) inhibitory mental control. These findings cast serious doubt on the theory that core brain-stem structures critically regulate the dream process.

Solms made a conceptual distinction between REM sleep, a physiological state, and dreaming. He pointed out that, although REM sleep has a high statistical correlation with dreaming, this does not mean that they are the same thing. He demonstrated that anything that disturbs sleep can give rise to a dream at any time, REM activation being but one such phenomenon.

The areas that are vital for dreaming include those limbic structures in which the basic emotion command systems are located, which are all highly active in REM sleep. This links dreaming to the processing of emotion. Solms concluded:

> 'in dreams, the primary "scene of action" of mental life shifts retrogressively, under the regulatory control of mediobasal frontal and anterior limbic systems, away from the dorsolateral frontal region which is the executive focus of normal waking cognition toward the parieto-occipital (perceptual-mnestic) systems. Nocturnal mentation is thus deprived of the characteristic goal-directedness of waking mental life, and the activating impulse is worked over symbolically in visuo-spatial consciousness.'

In light of the theories that we highlight in this article, we postulate that dreaming is one of the methods for updating prior predictions.

The results of Solms's study provide some striking corroboration of the classic theory of dreams introduced by Freud almost 100 years before.

Conclusions

Modern neuroscientific methodologies are stimulating research into a range of key psychological processes. This will continue to generate findings relevant to future psychiatric and psychotherapeutic practice across a variety of diagnoses, such as the role of interoception in anxiety, post-traumatic stress disorder, autism, schizophrenia and phobias (Garfinkel 2016), disorders of body awareness in neurological conditions and eating disorders (e.g. Crucianelli 2016), and latent vulnerability and the impact of maltreatment on emotional development and future mental health (McCrory 2015).

There is much work to do in coming years to understand the implications of neuroscientific findings for psychotherapeutic practice. For example, Solms demonstrates that key elements of Freud's theories are supported whereas others are being questioned. Some psychotherapists and group analysts (Bacha 2019; Bhurruth 2019) are beginning to explore the relevance for therapy. Conversely, psychotherapeutic models can generate hypotheses to test neuroscientifically. These developments will be facilitated by training clinicians in neuroscience and providing forums in which clinicians and neuroscientists can engage in dialogue and collaborative research.

In psychiatry, this article has demonstrated that interdisciplinary dialogue that integrates biological and psychological models yields innovative hypotheses, which can lead to new physical and psychological treatments. Still more far reaching are the implications for increasingly precise integrations of pharmacological, psychological and social treatments, some of which we have outlined. Opinion in psychiatry remains divided regarding the biological, psychological and social contributions to mental illness, limiting the scope for innovation and a holistic approach to practice. The current emphasis on neuroscience in the curriculum and the inclusion of relational and affective neuroscience brings with it the opportunity to bridge some of these divisions.

Author contributions

Both authors contributed sections to the article and collaborated over the style and structure.

Declaration of interest

None.

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MCQ answers
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MCQs

Select the single best option for each question stem

1 Jaak Panksepp's research:
- a endorses the James–Lange theory of emotion
- b demonstrates that DISGUST is one of the evolutionarily endowed emotion command systems
- c postulates that the emotion command systems give rise to affective consciousness
- d proposes psychedelic treatment for autism spectrum disorder
- e demonstrates that the emotion command systems are modulated through experience.

2 Consciousness:
- a arises in the cortex, as Freud first described
- b is only of interest to philosophers
- c in Solms's hypothesis arises from affect
- d is solely derived from exteroceptive stimuli
- e is the only way predictions can be updated.

3 Dreaming:
- a only occurs during REM sleep
- b utilises the same neural pathways as the LUST system
- c updates prior predictions on the basis of new information
- d is obliterated by lesions in the brain-stem
- e doesn't require arousal to trigger.

4 The Bayesian model of the brain:
- a proposes that the brain predicts how others will behave
- b is value free
- c proposes that prediction is solely a conscious process
- d proposes that data that do not fit perceptual reality are discarded
- e updates priors on the basis of new information.

5 The free energy principle:
- a was devised by Damasio
- b is not concerned with emotional stimuli
- c stipulates that interoception is a conscious self-reflective process
- d incorporates Freud's principle of free association
- e minimises homeostatic imbalance.

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