## Chapter 2

# The Impact of Play on the Developing Social Brain

## New Insights from the Neurobiology of Touch

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> [I]t is reasonable to believe that a substantial amount of social motivation emerges from the pleasure of touch, and the pleasure of play is strongly dependent on the sensation of touch … indeed it is possible that mammalian skin contains specialized receptors … for detecting social contact.
>
> (Panksepp, 2004, p. 271)

### Introduction

Touch is the first sensory stimulus we all experience of the world around us, starting at about 12 weeks prenatally. Although it has long been recognized that touch is essential to children's physical, cognitive and emotional growth, from infancy to early childhood (and beyond) few have asked "why?" or "how?" In this chapter we report on recent advances in neurobiology that have identified a specific population of mechanosensory nerves in the skin of the body that respond preferentially to the types of touch experienced during close physical contact, such as nurture from the mother or play with peers. These recently discovered (in humans) nerves are called C-tactile afferents (CT) and when stimulated generate a rewarding sensation that promotes behaviors involving close physical contact. The key message in this report is that stimulation of CTs is not arbitrary, it is essential for the development of a healthy body and mind – and the science supporting this claim is indisputable.

Article 31 of the UN Convention on the Rights of the Child, an international treaty that sets out universally accepted rights for children, states: "every child has the right to rest and leisure, to engage in play and recreational activities appropriate to the age of the child and to participate freely in cultural life and the arts." Play is known to be of fundamental importance to the social and emotional well-being of children, and at a neural level impacts on developing cognitive functions (Tamis-LeMonda et al., 2004; Singer & Singer, 2009). It is known from animal studies that enriched environments where animals are reared in close proximity to their littermates promotes brain growth and development as measured by enhanced performance on a number of learning tasks (Figure 2.1).

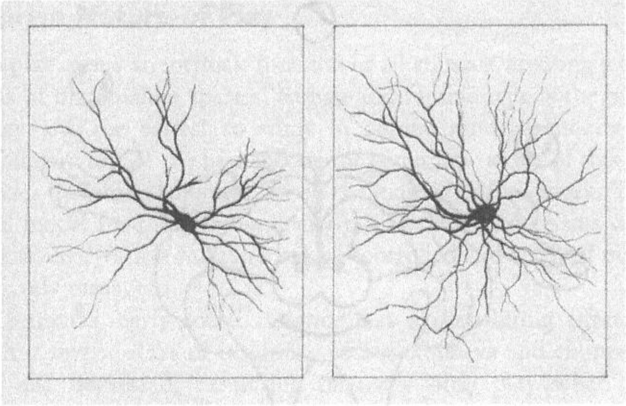

*Figure 2.1* Dendritic morphology of pyramidal neurons in somatosensory cortex in rat housed in (left) standard and (right) enriched environments. The enrichment significantly increases dendritic branching as well as the number of dendritic spines (cf. Johansson & Belichenko, 2001).

Illustration courtesy of Francis McGlone.

Of particular interest here is that this enhanced performance is linked to biochemical and structural changes in the hippocampus (a brain area involved in memory and spatial navigation) such as an increased number of dendritic branches and spines, enlargement of synapses and enhanced circuit connectivity (Kuzumaki et al., 2011). Childhood play stimulates the brain to make connections between nerve cells. Extremely deprived children who do not have enough opportunities to play also experience impaired brain development and cognitive flexibility (Else, 2009; Johansen-Berg & Duzel, 2016). This is what helps a child develop both gross motor skills (walking, running, jumping, and coordination) and fine motor skills (writing, manipulating small tools, detailed hand work). Play during the teen years and into adulthood helps the brain develop even more connectivity, especially in the frontal lobe that is the centre for planning and making good decisions.

### Background and Definitions

Jaak Panksepp was one of the first great neuroscientists to recognise the importance of play (or "social joy") in terms of its role in learning and development (Panksepp, 1991). The prescient opening quote of this chapter attests to Panksepp's recognition that there had to be a neurobiological basis for the play behaviors he observed, but the mechanism eluded him. By means of electrical stimulation, pharmacological challenges, and brain lesions of mostly mammalian vertebrates, Panksepp carved out seven primary

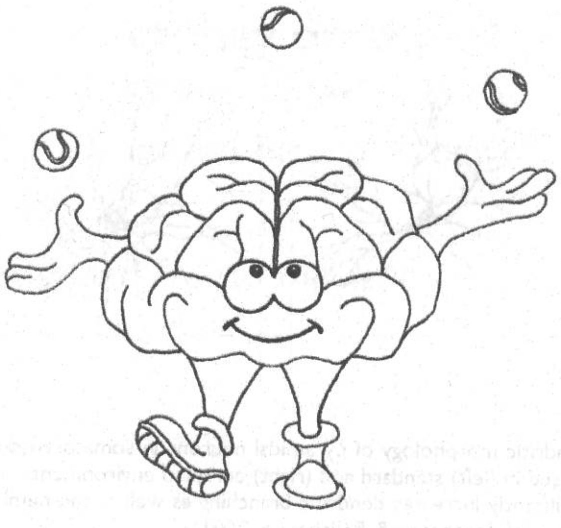

*Figure 2.2* Brains at play: What do we know.
Illustration courtesy of Francis McGlone.

emotional systems; play being one, along with seeking, care, lust, fear, sadness, and anger. In his seminal book *Affective Neuroscience: The Foundations of Human and Animal Emotions*, the late Panksepp wrote:

> to play is also to learn … play is fun for children, but it's much more than that – it's good for them, and it's necessary … play gives children the opportunity to develop their intellect, emotions and imagination through encouraging reward seeking behaviour.
>
> (Panksepp, 2004, p. 280)

Panksepp recognised that play/social joy is a complex system which stimulates young animals to regularly engage in physical activities like wrestling, running, and chasing, helping them to bond socially and learn social limits. Several forms of play are recognised in the human and animal literature, including sensorimotor play, relational play, constructive play, symbolic play, games-with-rules play, and "rough-and-tumble" play – also called horseplay, rough-housing, or play fighting. It starts in the toddler years and becomes increasingly common until late elementary or middle school. This latter form of play is exhibited by non-human mammals and is seemingly the most fun of all; however, it has received little attention in human research. Here we describe the specialised receptors in the human skin he speculated would be responsible for his observations of play.

## The Adaptive Nature of Play

The urge to play seems an intrinsic function of all animals, seemingly preserved in the brains of mammalian species. Rough-and-tumble type is the most basic form of play and the easiest to study in animal models; funnily enough, laboratory rats are one of the best species for systematic study of this behavior and the species on which Panksepp based the majority of his work. They provide a useful model for the systematic analysis of play mechanisms within the brain, as social-deprivation variables can be controlled and levels of playfulness can be effectively measured.

In most primates, early social isolation has a devastating effect on play instincts. After several days of isolation, young monkeys and chimps become despondent and depressed, exhibiting relatively little play when reunited. Juvenile rats, on the other hand, display the opposite reaction, with prior social isolation systematically increasing rough-housing play and social satiation reducing it. Rodents are better able to cope with social isolation compared to other mammals, likely because their social-bonding mechanisms are comparatively weak. Panksepp discovered that juvenile rats denied social interaction and prevented from engaging in play for up to 25 days demonstrated vigorous rough-and-tumble play behaviors as soon as they were given the opportunity. Rodent evidence shows that play reflects genetically ingrained impulses of the nervous system, and that the urge to engage in rough-and-tumble play is not created from past experiences.

## The Purpose of Play – Why is it Fun?

Play is often observed between siblings, parents and peers, and involves vigorous physically active behaviors such as being bounced, swung, lifted, wrestled, tickled or chased – many of which we have fond childhood memories of. The precise nature varies widely across different mammalian species; however, the general flavor remains the same – a competitive yet joyful social exchange. As with other types of play, rough-and-tumble play is important for healthy child development and is observed cross-culturally in children from preschool age to early adolescence (Frost, 1998; Paquette et al., 2003; Paquette et al., 2006), making it an important adaptive behavior – play requires no learning, it is an evolved behavior instinctively built into our heritage.

During development, the brain is especially sensitive to social information, and it seems that a great deal of learning occurs during the course of rough-and-tumble play. It helps shape a range of social, emotional and cognitive behaviors (McArdle, 2001), teaching children about their own abilities in comparison with others and helping them to develop social skills such as compassion, self-control and social boundaries. In addition, it has been found to improve preschool children's attention during subsequent learning tasks (Holmes, Pellegrini & Schmidt, 2006). However, due to its boisterous nature, rough-and-tumble play is often viewed as disruptive and is mistaken for aggression or misbehavior; it was initially discouraged by the US National Association for the Education of Young Children (Bredekamp & Copple, 1997). It is still often discouraged by adults and schoolteachers (Tannock, 2008) with many holding the belief that it would escalate into real fighting. However, Scott and Panksepp (2003) found this to occur less than 1 per cent of the time, and evidence suggests that allowing children to engage in rough-and-tumble play enables them to better distinguish between real fighting and play fighting in later life – this is also true for children with learning disabilities (Nabuzoka & Smith, 1999). In addition, the global increase in screen time and technology use and the fact that children have increasingly less time and safe spaces to enjoy this form of social play is leading to its decline, threatening its existence in the play of current and future generations. Rough-and-tumble play provides opportunities for children to balance two opposing social skills; competition and cooperation (Paquette et al., 2003). Its decline may lead to a generation of children with too much of either trait, leading them to become socially isolated and unable to work with others, or unable to assert or defend themselves. For example, MacDonald (1987) found a direct correlation between preschool boys' popularity and their likelihood to engage in rough-and-tumble play, furthermore, Orobio et al. (2005) found that children who are less successful at grasping the concepts of play fighting in early childhood are more likely to be less socially skilled and more aggressive adolescents.

Along with the many beneficial effects for both brain and body, including the facilitation of certain kinds of learning and various physical skills, play also serves a range of social functions. It facilitates young animals to effectively integrate into the structures of their society by enabling them to identify those who rank higher and lower than them, which individuals they can develop cooperative relationships, and those whom they should avoid. Play likely allows animals to develop effective courting and parenting skills, as well as increase their effectiveness in hostile situations by instilling knowledge about how and when to accept defeat. It is seemingly a socially contagious process – when playful urges arise in one animal, they seem to spread to others via some type of sensory/perceptual influence. With all of these important functions, it is not surprising that play is so much fun – a behavior humans and animals need to experience in order to develop emotionally, physically and cognitively, and become well-rounded social beings.

## Play and Parents

The full expression of play requires the right environment. In most mammals, play behaviors arise within their habitat/home environment (a secure base where parental support is available), and the most vigorous play occurs in the context of pre-existing social bonds. It is common in nature for infant–mother social bonds to be stronger than infant–father bonds, as fathers generally exhibit little-less enthusiasm for nurturing. Mother–offspring play is common throughout infancy, adolescence, and even adulthood, and the role of the mother in guiding play behaviors is evident in humans, chimpanzees and rats. However, even though fathers are less involved than mothers in most other aspects of child-rearing, physical play seems to be an exception (Bokony & Fortney, 2009).

Children benefit from play with both mother and father. In humans, fathers' play is typically more unpredictable and vigorous than the play of mothers, who are more likely to be cautious and engage in more pretend and object play (Paquette et al., 2003). The same study found that children experience more pleasure during rough-and-tumble play with fathers than mothers (Paquette et al., 2003), likely because male play tends to be more exciting and surprising. For example, fathers more often toss their children into the air or sneak up and grab them (Figure 2.3). For this reason, rough-housing with fathers seems to be

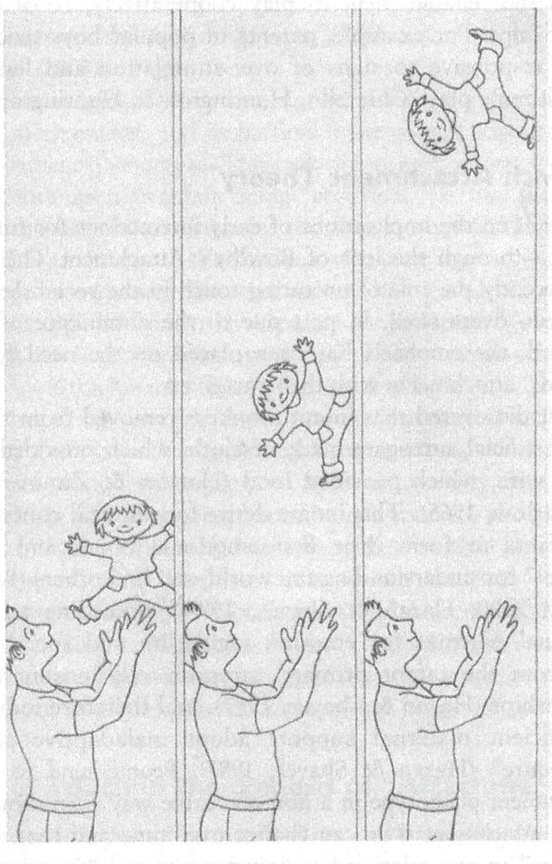

*Figure 2.3* Three perspectives on play seen from the child, the father and the mother. Illustration courtesy of Francis McGlone.

especially important in promoting problem-solving by teaching children how to deal with unexpected events (Bokony & Fortney, 2009), and may be especially important in teaching boys how to regulate their emotions and behavior (Canfield, 2002). Roggman et al. (2002) found that father–toddler physical play enhanced toddlers' cognitive and language development, despite mothers typically using more language than fathers when engaging in play with their offspring.

Children's playfulness is related to their parent's responsiveness (Chiarello, Huntington & Huntington, 2006). Sensitive and competent fathers maintain a sense of safety and security while stimulating and challenging their children during play, avoiding frustrating their child or getting them over-excited (Paquette, 2004). McArdle (2001) found that securely attached children display more flexibility and complexity in their play than insecurely attached children. Adult support during childhood play promotes secure attachment, self-regulation and social skills, which allows children to develop skills that enable them to play cooperatively, solve conflicts and develop friendships. For example, parents of popular boys tend to be more sensitive and responsive to signs of over-stimulation and less controlling over their children's play (Chiarello, Huntington & Huntington, 2006).

## Problems with Attachment Theory

A lot of research on the implications of early interactions for future development is viewed through the lens of Bowlby's Attachment Theory (Bowlby, 1973). Until recently the role of nurturing touch in the social development of infants has been overlooked, in part due to the dominance of Attachment Theory. Instead, the emphasis has been placed on the need for infants to develop "secure" attachments with their caregivers.

Harlow first discovered that infant monkeys removed from their mothers preferred an artificial surrogate made of cloth, which provided comfort, to one made of wire, which provided food (Harlow & Zimmermann, 1958; Harlow & Harlow, 1965). This innate desire for physical contact is thought to enable infants to form their first emotional bond, and an "internal working model" for understanding the world, self and others (Bowlby, 1973; Waters et al., 2000; Hazan & Shaver, 1987). According to Attachment Theory, internal schemas for emotion regulation and social relating are transferred from the infant–primary caregiver relationship to all other social relationships (Hazan & Shaver, 1987), and therefore individuals who receive insufficient maternal support adopt maladaptive schemas and become "insecure" (Hazan & Shaver, 1987). People tend to be given an insecure attachment phenotype in a non-revocable way even though researchers agree that attachment style can change over time and that an individual may be "secure" in one relationship/circumstance and "insecure" in another (Bowlby, 1973; Crowell et al., 2002; Fraley, 2002).

This deceptively simple theory has been adopted by many researchers over the years and has formed the basis of many subsequent theories of infant development. By recognizing the obvious importance of supportive maternal behaviors, Attachment Theory has been hailed a valuable tool for understanding and promoting children's well-being. Few people have questioned Attachment Theory, despite the fact that attachment classifications were not predicated on any scientific data. Instead, shared behaviors were clustered into a definition/diagnostic of "attachment style" resulting in a markedly reductionist compartmentalization.

Observations of attachment do have some veracity (as Harlow first noted), for example, individual differences in adult attachment have been found to influence psychosocial and somatic well-being, with a widely reported relationship between insecure attachment, and psychological adjustment problems, substance abuse and psychopathology (Brennan & Shaver, 1995; Griffin & Bartholomew, 1994; Mikulincer & Shaver, 2007). In addition, attachment relationships have been found to be important for establishing stress inhibition responses (Main, Kaplan & Cassidy, 1985; DeVries et al., 2003).

However, the original theory does not consider the importance of any neurobiological mechanisms, and in particular the role of touch, in the development of attachment phenotypes. This lack of recognition that the very nature of attachment relies upon an infant being "attached," i.e. that the physical touch between the mother and the infant is the critical stage in shaping the infant's psycho-social brain. Overall, the children who were more distressed as infants and did not receive as much physical contact had a molecular profile in their brain cells that indicated underdevelopment for their age. If touch is absent or compromized, as with Harlow's monkeys, all the criteria subsequently post-rationalized by Attachment Theory are observed. Recent insights from the licking and grooming behavior (touch) of rat mums finds that a pup from a low-licking grooming mother grows up to be anxious, whereas those from a high-licking grooming mother grow up to be calm adults (Figure 2.4) (Weaver et al., 2004). This difference is explained by epigenetics – the science of gene × environment (G×E) – describing how the epigenetic code is sensitive to changing environmental conditions such as a socially enriched environment and play. The impact of childhood experiences on adult mental and physical health is not yet fully understood but these results bring to light the ways in which the simple act of a parent's touch or the opportunity to engage in peer-to-peer play has deep and potentially long-term consequences on gene expression.

## The Role of Touch in the Genesis of "Attachment"

From the above it is clear that touch plays an important role in many forms of social communication and a number of theories have been proposed to explain observations and beliefs about the "power of touch." Research into

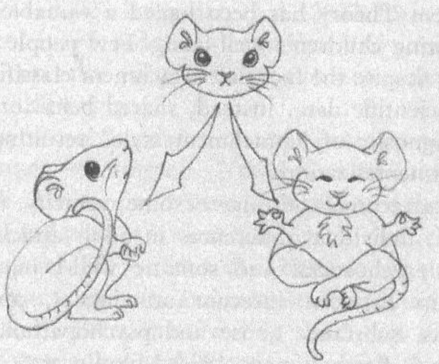

*Figure 2.4* Levels of early life touch experience determine the adult's ability to cope with stress.
Illustration courtesy of Francis McGlone.

the sense of touch in humans has largely concentrated on describing the sensory and perceptual consequences of stimulation of low-threshold mechanoreceptors (LTMs) and in a broader description the skin senses are often described as encompassing the four submodalities of touch, temperature, itch and pain. Each of these channels is capable of generating distinct sensory/perceptual qualities, processed by classes of stimulus-specific neurons that project in defined anatomical pathways to the cerebral cortex. Here, we propose that a recently discovered class of low-threshold unmyelinated mechanosensitive C-fibres called C-tactile afferents (CT), that innervate the hairy skin of the body, represent the neurobiological substrate for the affective and rewarding properties of touch, as experienced during play behaviors. CTs (or CLTMs in non-human mammals) have conduction velocities around 50 times slower than that of myelinated LTMs (Löken et al., 2009) and can therefore not provide information of any immediate relevance. Using the electrophysiological technique microneurography is has been found that CTs are specifically tuned to respond to *affective touch* – gentle, caress-like stroking (Nordin, 1990; Essick et al., 1999; Vallbo et al. 1999; McGlone et al., 2007; Löken et al., 2009; Ackerley et al., 2014; McGlone et al., 2014), making them considerably different from the myelinated mechanosensitive afferents responsible for discriminative touch. C-fibres, as a class of nerve fibre type, constitute the majority of afferents in peripheral sensory nerves, around 70 per cent (Willis & Coggeshall, 1978; Griffin et al., 2001) and evolved before the fast-conducting myelinated nerves. They have one key vital property – one of "protection." The significance of this is most clearly exemplified with the nociceptor (pain nerve) which plays a fundamental role in detecting potential or actual harmful stimulus or event occurring on or in the body, triggering defensive behavior. In the rare cases of children born with a congenital insensitivity to pain there is a lack in the ability to perceive physical pain (e.g. drinking a scalding hot beverage) and this lack of awareness often leads to health issues leading to the accumulation of multiple injuries and a reduced life expectancy. The CT performs an equally vital role in "protection," one that is only recently being recognized as we learn more about its functional role during development and throughout life. The Social Touch Hypothesis (Morrison et al., 2010) proposes that CTs code the hedonic and rewarding properties of touch and act as a peripheral pathway for pleasant tactile stimulation, encouraging interpersonal touch, attachment and affiliative behaviors, and perhaps mediating the emotional and rewarding properties of positive social touch. Unlike Attachment Theory, the Social Touch Hypothesis offers a mechanism highlighting the essential role of nurturing touch and linking its observations with a potential cause.

## The Somatosensory Control of Play

Research investigating the importance of the senses in social play has selectively eliminated both vision and olfaction, as, at least in rats, vision is not essential in generating playfulness as blind animals play with the usual vigor, and removing a rat's sense of smell does not reduce the overall amount of rough-and-tumble play observed. The auditory system seems to contribute to play to some extent – during and prior to play, rats emit 50 kHz laughter-type chirps, and play in deafened animals is slightly less. However, touch is the leading sensory system for the provocation and maintenance of normal play. Anesthetisation of an animal's body surface diminishes their ability to perceive proximal play signals (measured by dorsal contacts), and research in this area suggests that certain areas of the body are seemingly more sensitive to play-instigation signals than others. Local anesthetisation of the skin of the dorsal neck and shoulder area of young rats is highly effective in reducing the level of playful behaviors; however, this is not accompanied by a decrease in play-solicitation behaviors (i.e. dorsal contacts), indicating that motivation/desire for play is not reduced. This suggests that the basic desire to play is an endogenous process, but that if the sensory feedback from the skin is not there then the behavior ceases. If local anaesthetic is applied to a rat's rump, a significantly smaller effect on playful behaviors is observed, and no effects are observed when it is applied to the ventral surface (i.e. the animal's belly). This suggests that rats have homologous "play/tickle skin" located on the dorsal body surface – where most (but not all) play solicitations are directed (i.e. dorsal contacts). Panksepp et al., (2003) speculated that there would be skin sites that were innervated by specialised receptors which would send particularly potent somatosensory inputs to specific play circuitry of the brain/nervous system when they are touched in order to communicate playful intentions between animals. This is interesting, as rats' "play/tickle skin" areas correspond to those of humans (the back of the neck and around the rib cage) and areas where maternal grooming of rat pups is most commonly directed. The trunk, neck and head also happen to be the skin sites most densely innervated by CLTMs in rats (Liu et al., 2007) and the areas most finely tuned to slow gentle touch in humans (Walker, Trotter, Woods & McGlone, 2017). Understanding the neural processes underlying play systems may lie in analysis of the somatosensory stimulation of "play skin." The existence of cutaneous "neural play circuits" likely explains the phenomenon of tickling and helps answer the question of why we can't tickle ourselves (Blakemore, Wolpert & Frith, 2000). Therefore, the ability to identify and perceive play partners is a powerful, ingrained central nervous system concept (one that may have gone awry in autism).

## The Neuroanatomy of Play: The Brain's Play Networks

The developmental time course of rough-and-tumble play in most species exhibits an inverted U-shape, with play increasing during the early childhood, remaining stable throughout youth, and lessening during puberty. Although we can presume that this inverted U-shaped developmental function is related to aspects of brain maturation, as well as neurochemical shifts that occur during development, we currently know essentially nothing about the neurobiological factors that regulate it. Understanding the brain mechanisms underlying play could provide important insights into certain childhood psychiatric problems such as autism and attention deficit disorder. Within the last two decades, scientists have recognized that play is a primary emotional function of the mammalian brain, with a great deal of joy arising from the arousal of these play circuits. It recruits many brain abilities simultaneously, for example, most of the basic emotional systems are engaged at one time or another during play and therefore many neural circuits are expected to be involved. Neural systems that control movement
h as the vestibular, cerebellar and basal ganglia are likely to play a fun-
al role in play; however, this is not currently supported by any con-
idence since extensive damage to these areas compromises
plex motor abilities. For example, bilateral damage to the
t clei of infant rats abolishes play, but also appetite,
res ove (Panksepp, 2004). Lesions in other areas, such
cons oral lobe/amygdala and lateral hypothalamus, also
ay; however, again, the overall conduct of the animal

becomes so impaired that it prevents any meaningful interpretation with respect to specific play systems.

The symptoms of frontal lobe damage generally resemble Attention Deficit/Hyperactivity Disorder (ADHD), and right hemisphere frontal lobe lesions significantly increase playfulness in rats (Panksepp et al., 2003). Rodent models implicate frontal lobe deficits in ADHD and suggest that these brain areas contribute to the developmental processes which diminish play as animals mature. The authors suggested that one of the long-term functions of social play may be to promote maturation of various higher brain areas, including frontal cortical regions responsible for behavioral inhibition and the regulation of excessive play urges often reflected in impulsive behaviors characteristic of ADHD (Panksepp et al., 2003).

However, in animal models of neonatal decortication (surgical removal of the cortex) play motivation is not eliminated or play behaviors greatly affected in rats (Panksepp et al., 1994), suggesting that the primary process of play is deeply embedded in mammalian brains. Despite this, it seems clear that play has powerful effects on the cortex. C-fos expression is used as a marker for neuronal activity throughout the neuroaxis following peripheral stimulation; play elevates c-fos expression in medial thalamic areas such as the parafascicular and hippocampus, and in many higher brain areas, especially the somatosensory cortex. This evidence suggests a role of play in the development of various cortical functions. Smaller lesions are much more interpretable, and as of yet, specific play motivation effects have only been observed in the case of bilateral damage to the nonspecific reticular nuclei of the thalamus, such as the parafascicular complex and posterior thalamic nuclei. When the parafascicular region of the thalamus is lesioned in rats, play solicitation behaviors (i.e. pinning and dorsal contact) are reduced, indicating diminished play motivation compared to controls. However, other rather complex motivated behaviors, such as foraging, are not reduced (Siviy and Panksepp, 1985a, 1985b). This suggests that nonspecific reticular nuclei of the thalamus specifically mediate the urge to play.

The parafascicular thalamic nucleus is also thought to play a role in pain perception, as it contains neurons that respond to noxious stimuli such as pinpricks. However, it may be that these stimuli more closely resemble nipping or tickling than pain. This may explain why in humans, intense/prolonged tickling is almost unbearable. In addition, human laughter systems have also been associated with these primitive subcortical brain areas. For humans, the hallmark of play circuitry in action is laughter, which some have argued may emerge from play motivation. Amyotrophic lateral sclerosis (ALS) – a demyelination of motor neurons affecting the brain stem, along with gelastic epilepsy, are two neurological diseases accompanied by impulsive bouts of laughter in the absence of any positive affect. Interestingly, earlier phases of these diseases typically involve pathological crying, again in the absence of any sadness. This apparent relationship between laugher and crying suggests that they are intermediately related in the brain, with the ability to cry – a separation-distress, and social-bonding mechanism acting as a prerequisite for the evolution of laughter, and possibly play. This is supported by the fact that crying seems to emerge from lower levels of the neuroaxis.

The prevailing sensory system, which both provides comfort after separation and most readily provokes play, is touch. Therefore, in evolutionary terms the pleasure of affective touch may have established a neural framework for the emergence of play. If so, we might suppose that both play and laughter serve social-bonding functions – possibly helping us to discriminate friends and family from strangers.

## The Neurochemistry of Play

According to Panksepp: "play is both a robust and a fragile phenomenon." Environmental manipulations aroused in a play context, which evoke negative emotional states such as fear, anger, and separation distress are surprisingly effective in reducing play. In addition, homeostatic imbalances such as hunger and bodily imbalances (i.e. illnesses) are powerful play inhibitors. Many of these negative factors have neurochemical underpinnings, and inhibiting play using drugs is remarkably easy; however, it is very difficult to determine whether these effects reflect specific changes in underlying play regulatory mechanisms or merely the generally disruptive psychological and behavioral effects of drugs. Despite this, there is currently considerable evidence that opioids specifically mediate play motivation, with low doses of opiate agonists increasing play behaviors, and opiate antagonists reducing them. For obvious reasons, to facilitate play, doses must be kept low, as opiate arousal over a certain point induces catatonia and inhibits the desire for all forms of social interaction including play. Indirect evidence from autoradiography studies suggests that during play there is a widespread release of opioids in the nervous system, especially in brain areas such as the medial preoptic area/anterior hypothalamus, where sexual and maternal behavior circuitries are situated. There is also a role for endogenous opioids in gentle touch behaviors – endorphins modulate pair bonding and attachment in primates and other mammals. Keverne et al. (1989) found that grooming duration related to changes in rhesus macaque's neural opioid systems, and Johnson and Johnson and Dunbar (2016) found that the density of human endorphin receptors corresponds with the size of an individuals' social network. CT-targeted touch has been found to activate similar neural pathways in humans to those that fire in rhesus macaques during grooming, triggering the same release of endorphins (serotonin & oxytocin) and endogenous opioids (Keverne et al., 1989; Walker et al. 2017).

When placed with controls and animals treated with low doses of morphine, animals treated with naloxone (an opioid antagonist) become submissive and lose during a wrestling match situation. However, when placed with a partner treated with scopolamine (a cholinergic blocking agent making them totally non-reciprocating and non-threatening), animals treated with naloxone at doses that normally reduce play exhibit heightened play solicitations, winning during wrestling matches. This is because naloxone-treated animals, when paired with scopolamine treated animals, and morphine treated animals/controls, when paired with animals treated with naloxone experience heightened social confidence and feelings of social strength. Therefore, brain opioids may control social emotionality – which may be why without them, an animal is more prone to experience negative affect and feelings such as separation distress and reduced psychological strength, and likely why we see a reduction in play solicitation following the release of opiate antagonists. However, there are alternative explanations; opiate receptor antagonists may reduce or eliminate the reinforcing pleasure of social interaction, while opiate agonists enhance them. It is also possible that morphine dulls the pain of playful scrapes, while opiate antagonists make them more painful.

However, opioids cannot be the only factor modulating play, as it is not possible to restore playfulness in older rats or play-satiated youngsters by administering low doses of opiate agonists or antagonists. Many other neurochemical systems appear to have specific effects on play. For example, acetylcholine appears to promote play, as blocking cholinergic activity with scopolamine markedly reduces play solicitation behaviors in rats. However, as of yet, no one has been able to directly enhance play by activating the cholinergic system. Neurotransmitters serotonin and noradrenaline also reduce play, while blocking their receptors can increase play to some degree. Conversely, blocking dopamine receptors reduces play, and most dopamine agonists do the same, indicating that play requires animals to have normal levels of synaptic dopamine. A significant amount of research has been conducted on hormone production in parents. In fathers specifically, active "rough-and-tumble" interactions have been positively correlated with oxytocin (Feldman et al., 2010) and testosterone production (Rilling & Mascaro, 2017), whereas empathy-related caring behavior would be negatively correlated with testosterone (Fleming et al., 2002; Mascaro et al., 2014; Weisman et al., 2014).

Panksepp dedicated a lot of his time searching for a way to "turn on" playfulness pharmacologically; however, all neurochemical systems participate in the control of a large number of brain and behavioral processes, and virtually all of them must be administered directly into the brain's synapses. Currently we don't know enough about play circuitry to accurately administer these substances. The brain may contain highly specific play-promoting neurochemicals; however, no such substance has yet been identified.

## Conclusion

The basic desire to play is an endogenous impulse. The brain contains distinct neural systems for the generation of all types of play involving the thalamus and cortex – midbrain somatosensory information processing centres. Modest brain opioid arousal promotes play, and ongoing play promotes opioid release, which may serve to gradually bring play episodes to an end. Since rough-and-tumble play arises from powerful neural activities which interact with many forms of learning, it is difficult to study comprehensively, and due to the complexity of the motor features of rough-and-tumble play, it is difficult to trace the source mechanisms in a systematic manner. Only when play can be "turned on" pharmacologically in animal models will we truly understand the neural underpinnings of playfulness, but even then its adaptive functions may be indefinite. Given the social significance of touch and the fact that the physical embodiment of attachment is touch, it's not unlikely that the CT-system represents an evolutionary mechanism responsible for promoting normative social development and the development of adaptive, "secure" attachment behaviors. It is also reasonable to hypothesise that the pleasure of touch may have established an evolved neural framework for the emergence of play.

### *Discussion Questions*

1. What does the skin tell the brain?
2. Discuss the effects a lack of nurturing care had on Romanian orphanage infants.
3. Attachment has a nerve. Discuss the relevance of attachment in the light of recent evidence of C-tactile afferents.

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## Chapter 3

# Neurosensory Play in the Infant–Parent Dyad

## A Developmental Perspective

*Ken Schwartzenberger*

## Preborn Neurosensory Development

Neuroscience and developmental psychology research has advanced our knowledge of early in utero experiences of preborn infants. The heart starts beating at six weeks and development of the brain begins during the first eight weeks of the embryonic period. The preborn infant's brain is organized and develops from the bottom up, starting with the brain stem, followed in sequence by the limbic brain and the neocortex brain systems. The brain is made up of specialized nerve cells (neurons) which communicate with one another via electrical and neurochemical signals and form new networks of connections and neural patterns every time the brain is stimulated (Perry, 2006).

The sensorimotor level of information processing, including sensation and movement, is initiated primarily in the brain stem. Sensory system receptors receive incoming stimuli via afferent nerves and send this information via efferent nerve pathways to the thalamus and across a synapse to the amygdala and the limbic brain system (Lillas & Turnbull, 2009). The structures of the limbic system are involved in emotion, motivation, learning, and memory. The physical and emotional needs of infants are dominated by the brain stem and the limbic brain systems (Lillas & Turnbull, 2009).

The neurological system is one of the first systems to develop in utero and consists of the central and sensory nervous systems. The central nervous system includes multiple branches that control intake and responses to sensory input. These neural circuits include the autonomic nervous system in the brain stem that regulates heart rate and breathing.

There are two branches of the autonomic nervous system, the sympathetic (activation) and the parasympathetic (inhibition) nervous systems. There are two branches of the parasympathetic nervous system, the ventral vagal (slow down) and dorsal vagal (shut down) nervous systems. The vagal nerve is central for the infant to sustain attention, regulate emotions, control heart rate variability, and engage in social emotional play interactions (Porges, 2011; Kestly, 2014).