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# The neurophysiology of empathy

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## 13.1 Theories of empathy

### 13.1.1 Evolutionary theories of empathy

Darwin (1872) contended that emotions are primary regulators of social interaction and that interspecies communication of emotion is innate and has adaptive value. Within this framework, empathy, which involves recognizing emotions and adjusting social interactions accordingly, would provide individuals and groups who possess this ability with an evolutionary advantage.

Several contemporary theoretical papers have also emerged in the psychological literature that discuss the evolution of empathy and its neural substrates. For example, Brothers (1989) introduced an evolutionary theory of empathy, defining the concept of empathy across maturational levels. He and others (Hoffman, 2000; Trevarthen & Aitken, 1994) argue that empathy is an innate biologically based process in more evolved species. Empathy's evolution in phylogeny and ontogeny is based on the need for more evolved species to be able to communicate with important others, such as caretakers and attachment figures. While the theoretical models proposed differ in the exact mechanism impelling the development of empathy, they agree that variation between individuals in levels of empathic processing derives from evolved variation in genetic endowments and is modified by environmental experiences. Ultimately these theories recognize that empathy, a key component of social communication during development, is adaptive, promotes survival and has a neurological basis.

### 13.1.2 Somatic theories of empathy

The somatic theories have their origins in the writings of William James (1884) and Walter Cannon (1927), with James arguing that emotions were intertwined with bodily sensations and Cannon focusing on the brain's role in emotion.

*Empathy in Mental Illness*, eds. Tom F.D. Farrow and Peter W.R. Woodruff. Published by Cambridge University Press. 

Contemporary theories, such as Damasio's Somatic Marker Hypothesis (Damasio, 2000) and Porges' Polyvagal Theory (Porges, 2003), rely heavily on the workings of neurological systems to explain the progression of emotions and the associated bodily changes in response to environmental events. Employing a brain–body connection to investigate individual differences in emotional reactivity and regulation (Doussard-Roosevelt *et al.*, 2001), these theories are important because they contribute to our understanding of how entire systems can be involved in coordinated functioning for empathy.

### 13.1.3 Individual differences theories of empathy

A final group of theories converge on the issue of individual differences in reactivity and arousal. Historically individual differences were examined when potential risk for physical or psychological impairments, as a result of neurophysiological injury or socially mediated dysfunction, were uncovered. The most well-known case of injury to the brain is the case of Phineas Gage (Harlow, 1868), which documented dramatic changes in personality, including decreased ability to display empathic responses. Similarly, individual differences in dysfunctional emotional processes also stemmed from socially mediated syndromes/illnesses, as reported by the clinical case studies of Freud (Freud & Breuer, 1895). However, scientific investigation of the connection between emotions and neural systems was not undertaken because neurones were not well understood and there were methodological constraints in studying brain function at the time.

More recently, scientists (Gainotti, 1989) provided empirically based descriptions of differences in brain dysfunction and the associated emotional consequences, describing 'catastrophic reactions' in left-hemisphere-lesioned patients and reactions of indifference in right-hemisphere-lesioned patients. Moreover, Robinson and his colleagues (1984) demonstrated that there was localization of emotional responses to the anterior regions of the brain, impelling further theoretical interest and empirical studies on the specialization of the two hemispheres as well as specialization of the anterior region for the processing of emotionally relevant stimulus events.

Developmental studies have investigated these models. For example, Fox and his colleagues (Fox, 1991; Fox *et al.*, 1994) contend that individual differences in emotional reactivity are innate, neurophysiological processes, stemming from the motivational tendencies for approach versus withdrawal, a continuum that has both behavioural (Carver, 2001) and physiological (Fox *et al.*, 1994) sources of verification. As such, an individual's emotional experience is the result of two differing systems in the organism: the motivational tendency for approaching novel and interesting events or situations in order to explore and learn, versus the tendency for withdrawing or escaping from repugnant and potentially damaging events or environments. Neurophysiological correlates of the approach–withdrawal continuum have also been documented by Fox and his colleagues (Fox *et al.*, 1994), with the approach system associated with the development of left frontal brain activity patterns and the withdrawal system associated with right frontal brain activity patterns.

Empathy is conceptualized in this model as a complex emotion emerging and unfolding from the approach system. For instance, the approach motivation system undergirds infants' and children's interest in novel and social events and enables the subsequent development of concern and responsibility (Fox, 1991). Empirical studies have focused on delineating individual differences in innate dispositions, the associated involvement of neural systems, and the role of environmental modifiers affecting the dispositions during normal development (Fox *et al.*, 1994). Fox example, Young *et al.* (1999) demonstrated that individual infants with lower arousal patterns showed less empathy during toddlerhood than infants demonstrating higher arousal patterns. Further, children who were labelled as behaviourally inhibited (a withdrawing tendency) were less empathic with an unfamiliar adult than children not prone to inhibited behaviours. While somewhat limited, these data suggest that specific patterns of temperamental reactivity can be predictive of empathic responding and patterns of risk for empathic dysregulation.

In a complementary series of theoretical and empirical papers based in individual differences theories, Davidson (Davidson, 2004; Tomarken *et al.*, 1990) have focused their efforts on outlining the association between brain functioning and socioemotional risk factors for psychopathology. In their view individual differences in genetic and neurophysiological processes form a potential diathesis and specific environmental stressors experienced by individuals with this diathesis may have an increased risk for psychopathology. Davidson's theories, primarily focusing on delineating the basis for depression, have expanded the scientific understanding of the lateralization and specialization of brain regions for understanding individually based predispositions for psychopathology. Empirical work by Davidson and his colleagues has associated EEG asymmetries with: (1) positive and negative emotional experiences (Tomarken *et al.*, 1990); (2) individual differences in risk for psychopathology (Davidson, 2004); and (3) potential mechanisms responsible for psychological well-being (Urry *et al.*, 2004).

In summary, individual differences theories attempt to elucidate risk and protective factors that contribute to adaptive versus maladaptive emotional processes. Using this theory to understand individual differences in empathic reactivity and neurophysiological correlates associated with changes in empathic processes across development will provide essential information to understand the nature of empathy in humans.

## 13.2 EEG activity – a method of measuring brain–behaviour relations

Multiple methods have been used to study brain functioning, among them the patterns of electrical activity recorded by an electroencephalogram (EEG). The electrical activity present at the scalp that is measured by the EEG represents the fluctuation of excitatory and inhibitory postsynaptic potentials across time. During the last 75 years, much progress has been made in understanding the genesis and dynamics of the human EEG (Fox *et al.*, 2000). Neuropsychological reports suggest that cortical pyramidal neurones are responsible for the electrical activity recorded from the surface of the scalp (Thatcher & John, 1977).

In addition, recent reports suggest that the activity of cortical pyramidal neurones could be regulated, in part, by subcortical inputs including the limbic circuits that may indirectly generate electrical activity at the scalp (Davidson, 2004). Thus the electrical activity recorded by the EEG reflects the extracellular potentials of nearby cortical neurones, whose activity is modulated by a wide range of cortical and subcortical inputs. As such, mental states including cognitive processing, affective states and arousal levels will alter the activity and synchronization of underlying cortical neuronal networks, resulting in electrical potentials with distinct characteristics.

Several different measurement properties of the EEG have been viewed as useful for investigating brain and behaviour relations, among them are: (1) the frequency components, (2) the power spectra at different points in development and (3) the specialization of different hemispheres within various regions of the brain (also referred to as EEG asymmetry or hemispheric lateralization). The frequency composition of scalp electrical activity remains the most widely studied component of the EEG signal. Even though the frequency range for the human EEG ranges from very low to very high frequencies, the vast majority of research conducted on EEG and emotions, however, has focused exclusively on activity within the alpha frequency band (traditionally defined at 8–13 hertz in adults). Alpha activity is mostly sinusoidal in form and can be recorded over widespread scalp regions and it shows a linear increase in amplitude from anterior to posterior regions (Nunez *et al.*, 2001). Alpha activity is reciprocally associated with cortical activation inasmuch as amplitude and synchronized rhythmic frequencies in the alpha band activity are attenuated during mental activity (Nunez *et al.*, 2001).

During development dynamic changes in the brain (i.e. synaptogenesis, mylenation of the axons, and hemispheric integration across the corpus collosum) present simultaneously challenging and intriguing problems. Both measurement issues and functionality questions arise. Increases in EEG power, magnitude and peak frequency signal maturation of the brain, making the spectral properties of the human EEG important measures of development. However, the spectral properties differ within specific regions of the cortex across development. Studies have reported a shift downward in the spectral properties of the EEG during infancy and childhood, suggesting that it would not be meaningful to use the adult frequency band definitions to study infant and child EEG patterns (Pivik *et al.*, 1993). During the first year of life the majority of EEG activity occurs within the 3- to 12-Hz frequency band (Jones *et al.*, 1998) showing a peak of 6–9 Hz at around six months of age (Bell, 1998; Bell & Fox, 1994). Using a wider frequency band that encompasses all frequencies in which there is a substantial amount of power (i.e. 3–12 Hz) or using a narrow frequency band centred around the peaks in the spectrum (i.e. 6–9 Hz) (Pivik *et al.*, 1993) is still being debated. In addition, the functional abilities of the different regions of the cortex during infancy and childhood have been under question. Specifically, the frontal lobes have been ignored by some researchers, as they have a more protracted course. However, neuroimaging and neurophysiological studies (Chugani, 1994; Fox *et al.*, 2000) have shown that the frontal cortex is not inactive during development and may in fact provide the more intriguing functional information during the process of maturation. Studies have demonstrated important associations between emotions and frontal EEG activity in infant participants (Jones *et al.*, 1997, 1998).

With increasing intercommunication between hemispheres (Fox *et al.*, 1994), computation of EEG asymmetry values have also been utilized extensively in adult and developmental research paradigms. EEG asymmetries are comparisons between relative power scores within the left compared to the right (or the right compared to the left) hemispheres. These measures of the relative power in the brain's electrical activity have been associated empirically with several processes including the current emotional processing of various states (Tomarken *et al.*, 1990), the regulation and modulation of emotion (Fox *et al.*, 1994) and/or the predisposition for certain traits, personal styles and potentially for psychopathology (Davidson, 2004; Jones *et al.*, 1998, 2000).

In summary, the electrical activity of the brain can be measured by an EEG, a measurement of cortical pyramidal neurones influenced by cortical and subcortical inputs. During development the spectral properties of the EEG change yet these properties and their relation to affective processes have provided information important to the understanding of the neural basis of temperament and potential risk for psychopathology. Compared to other measures of neural–behaviour investigations, the advantage of measuring EEG activity is its superior temporal resolution, making it ideal for studying rapidly changing physiological processes such as empathy and for studying the development of emotions including empathy. The primary disadvantage is its poor spatial resolution, a problem that can be remedied by studying measures of EEG activation in corroboration with other measures of neural functioning that have good spatial resolution such as PET scans and fMRI (Davidson, 2004).

## 13.3 Overview of associations between brain regions and empathy

Multiple systems in the subcortical and cortical regions of the brain control nearly all types of human behaviours including the emotional and representational processes associated with empathy. In this section the neural circuitry implicated in empathic processes will be reviewed. In order to understand the neurophysiology of empathy, it is necessary to grasp the complexity and interdependence of the multiple structures and hierarchies of the neural systems involved. It is equally important to comprehend the interdependence of the motivational and emotional processes initiated and maintained during the experience of empathy. This includes understanding the subprocesses involved in empathy, such as perception, bodily sensations, attention, memories, motor programs, as well as the mental representations of the self, others and the social environment. Although a number of subcortical regions are involved in these processes at a microanalytic level (e.g. the cerebellum's role in attention shifts and the hypothalamus' role in maintaining homeostasis) the focus of this section will be on the higher neural systems implicated during the processing of empathy. From a physiological perspective, the processes of empathy include: (1) the limbic circuitry (subcortical areas with elaborate interconnections to the cortical region); (2) the temporal cortex (implicated in processing emotional memories); (3) the frontal cortex (especially the hemispheric specialization of the prefrontal cortex which has been identified as a source for the regulation of emotions); and (4) the autonomic nervous system (a system that activates the action sequence for the response).

### 13.3.1 The limbic circuitry

While some have argued that delineation of the structures within the 'limbic system' is arbitrary (LeDoux, 1996), studies of the limbic circuit's role in emotion-related processes have continued. Neuroscientists conceptualize the limbic circuitry as an interacting network of structures (Trevarthen & Aitken, 1994). Major connections of limbic circuits include the prefrontal and sensory association cortexes that connect with the cingulate cortex, the hippocampal formation and the amygdala, with these last two structures connecting to different regions of the hypothalamus, which in turn connect to the cingulate cortex through the anterior thalamus (Kandel *et al.*, 2000).

Although much is known about the anatomy of the limbic structures and the pathways that connect them to each other and to other parts of the brain, exactly how they function in emotion and empathy is still largely conjecture. How are structures in this system implicated in emotional and empathic processes? The answer to this question depends on the type of process within empathy that is being assessed. For example, the amygdala responds fast (as in emotions such as fear) and has ascending projections to the cortex. Researchers have suggested that this pathway may allow the amygdala to modulate and/or regulate the cognitive processes transferred to the cortex (LeDoux, 1996). Thus during emotional processes such as empathy, the amygdala may function by helping to associate external information (e.g. another person's emotion) with internal representations (e.g. one's own episodic memories of that emotion) and the associations that include incentive for rewards to motivate helping or alternatively punishments that inhibit helping. In other words, the amygdala-to-temporal-to-frontal cortex connection may function to assist in memory consolidation or matching memories of moods to current emotional states, via the hippocampus and temporal lobe, and then regulating emotional content during empathy-eliciting situations via the prefrontal cortex. Moreover, Panksepp (2000) has proposed that the anterior thalamic to cingulate system, including the septal areas and the hypothalamus, is involved in attachment and affiliative behaviours. Another structure in the limbic system that plays a significant role is the sensory association cortex, an area that is thought to integrate sensations in the self and those involved when observing another's emotional state. Additionally, the limbic circuit has numerous projections to the cingulate and frontal cortexes, areas that are implicated in the perception and regulation of emotions. In sum, while the limbic circuitry plays an important role sensing, perceiving and relaying empathy-based information, the control and regulation of empathy are accomplished by the interaction of limbic circuits with higher cortical areas.

### 13.3.2 The temporal lobes

The position of the temporal lobe in relation to the prefrontal lobes (especially the dorsolateral and ortibal areas) and the limbic system makes it an essential cortical structure for empathy, as the temporal lobe is below the Sylvian fissure and directly anterior to the parietal and occipital lobes. Further, the subcortical temporal structures include the limbic circuitry, the amygdala and the hippocampal formation.

The temporal lobe is involved in multimodal matching of sensory information, facial expressions (primarily the right temporal lobe), memories (primarily the left temporal lobe), content evaluation of sensory stimuli and spatial navigation, all of which are important processes related to empathy (Kandel *et al.*, 2000). Emotion requires perception of the stimulus with subsequent communication to areas of the brain that are responsible for the production of emotions; empathy requires an additional component of imitating the production of the emotional event. In a model proposed by Iacoboni and Lenzi (2002), the temporal region functions in an essential way to relay and coordinate the frontal to parietal lobes and the associated limbic circuitry to produce the experience empathy. Specifically their model focuses on the insular to frontal connections, which are believed to be the circuitry involved in communication of the feeling tone in empathy. Using fMRI, Iacoboni and Lenzi (2002) have provided some support for their model in human imitation studies of facial expression; however, active imitation did not show any more insular activity than passive viewing of facial displays while the insular to frontal connections demonstrated more fMRI activity during imitation, suggesting that frontal lobe involvement may be more important for processing empathy.

### 13.3.3 The frontal lobes

The frontal region of the brain includes: (1) the motor cortex, which is responsible for movements; (2) the premotor cortex, which is responsible for selecting movements (including planning, sequencing and preparations for executing motor actions); and (3) the prefrontal cortex, which is responsible for the integration of cognitive and emotional processes inasmuch as appropriate movements are selected for specific environmental contexts (Kandel *et al.*, 2000). While the prefrontal cortex is functionally heterogeneous, much of this area has been shown to be fundamentally related to processes that are necessary for emotional and empathic responses. Three sectors of the prefrontal cortex implicated in empathic processes are the dorsolateral, ventromedial and orbital areas. The dorsolateral region is believed to maintain, manipulate and select working memories (Bell, 1998; Davidson, 2004), in as much as the memories deemed important are maintained within the mind and alternative responses are considered, a process in which other sensory, limbic and motor areas are activated to guide behaviour (Davidson, 2004). In addition, evidence suggests that the dorsolateral sector of the prefrontal cortex is mainly involved in representational processes while the ventromedial area maintains memories and combines both short- and long-term goals into a behavioural response. Further, associations between ventromedial prefrontal cortex asymmetries and behavioural responses may include the ability to inhibit a response in order to obtain a selected goal (Tranel *et al.*, 2002). For example, response inhibition would be important for empathy, as the emotion must be felt for another to maintain the relationship (the goal) whereas if the emotion is felt directly for oneself then it does nothing for the relationship with another. Finally, the orbital areas, both frontal and lateral, are thought to be involved in assigning affective significance to contexts or events (Hornak *et al.*, 2003).

That the two hemispheres of the frontal region of the brain may have unique and increasing involvement in the processing of emotions associated with empathy has only begun to be investigated empirically (Davidson, 2004; Fox *et al.*, 1994). As the brain becomes more integrated across development both regions appear to play a role in emotional processes. Further each hemisphere has been shown to have a specialized role. As reviewed previously, the left frontal region has been shown to be specialized for the processing of positive, approach-related emotions whereas the right frontal region processes negative, withdrawal-related emotions (Davidson, 2004; Fox, 1991). This would imply that both hemispheres are involved at different stages in the processing of empathy; however, it suggests that the left hemisphere regulates the experience of empathy, as empathy is an approach-related response (Jones *et al.*, 2000). Much more work on these specializations of the two hemispheres needs to be accomplished before definitive conclusions can be drawn. Moreover, the relationship between hemispheric specializations and the development of emotions in general needs further support and delineation.

### 13.3.4 The autonomic nervous system

Finally, previous studies have demonstrated that there are important autonomic nervous system (ANS) correlates of empathy (Zahn-Waxler *et al.*, 1995), correlates that are integrated with cortical functioning (Fox, 1991; Porges, 2003). Much of the workings of the brain are through its control of the bodily systems, making the study of ANS processes central to the study of empathy. From a physiological perspective, the ANS includes the sympathetic and parasympathetic branches, each working together but performing antagonistic functions. Simply stated, the sympathetic system activates the bodily energies and the parasympathetic system conserves energy and resources. Thus one could argue that the ANS implements the intensity of the emotional response through its control of bodily processes.

During the process of empathy, the sympathetic system is believed to be associated with the initial response of alert to another's distress while the parasympathetic system enables the observer to regulate their own emotional arousal to facilitate helping and prosocial behaviours. Although scientists have recognized the ultimate control of the neural circuits, the preponderance of developmental studies, to date, have been on the relationship between autonomic measures and empathic responses (Zahn-Waxler *et al.*, 1995).

## 13.4 Empirical studies of the neurophysiological substrates of empathy

### 13.4.1 In development

While there is a plethora of empirical evidence that supports the anterior region's involvement in adult cognitive abilities, moods and emotional disorders

(Davidson, 2004), relatively fewer studies have investigated the child's developing empathic skills and the associated higher cortical functioning. Part of the reason is simply that brain processes during development are not well understood and are challenging to measure. For instance, EEG interpretation guidelines used in adults are not applicable to children and hemispheric specialization in emotional reactivity has only recently been uncovered (Fox *et al.*, 2000; Pivik *et al.*, 1993). Additionally, the right and left hemispheres of the frontal lobes appear to mature at different rates. Further the left frontal region, the region most implicated in empathy, shows a slow and multifaceted developmental course (Bell, 1998; Bell & Fox, 1994; Chugani, 1994). In short, while brain function in children appears to be different than brain function in adults, little is known about the meaning of those differences. Are certain parts of children's brains underdeveloped or do they simply function in a qualitatively different way at this age? That question remains unanswered; however, developmental neurophysiological studies are the most promising area of investigation for uncovering risk and protective factors during the development of social emotions.

While this area of research is still relatively new, a number of associations between physiology and empathy have nonetheless been investigated. Three very diverse and sometimes disparate lines of research have implicated the cortex, specifically the frontal region, in the development of empathy. These three theoretical approaches are reviewed below.

### 13.4.2 Biobehavioural preparedness

Several researchers have posited the theory that humans are born with, to varying degrees, a biological preparedness for social interaction (Brothers, 1989; Hoffman, 2000; Trevarthen & Aitken, 1994). Studies designed to investigate this ability have shown that newborn facial expressions can be reliably measured and are accompanied by a physiological and measurable response (Field, 1989). This has been interpreted to indicate an innate capacity for responding emotionally to social information from others. That infants model fear, distress, disgust and surprise, and attend to happiness, sadness and surprise underscores the importance of the communication of emotions (Field, 1989).

Notably, early studies of newborn facial expressivity merely argued that newborns reflexively copied faces that were observed, suggesting that newborns neither felt the emotion nor did they have their own characteristic style of responding. Most developmental scientists, today, believe differently, as current studies have linked the production of facial displays with simultaneous changes in autonomic and neural processes, which is an indicator of individual differences in response styles (Field, 1989). For example, studies by Field and her colleagues (Field, 1989) have demonstrated that those newborns with high emotional expressivity exhibited low heart rate variability and low heart period (higher heart rate) whereas those with low emotional expressivity exhibited high heart rate variability and high heart period (lower heart rate). Additionally, we (Jones *et al.*, 1997) demonstrated that right frontal EEG asymmetry was related to more distress expressions in infants. Further, individual differences in emotional reactivity and physiological regulation were present from birth, with infants of depressed mothers showing less emotional responsiveness at birth, greater physiological dysregulation and less empathy later in childhood (Jones *et al.*, 1998, 2000).

Research has also shown that newborns respond with distinct behavioural patterns to the distress of another (Dondi *et al.*, 1999; Hoffman, 2000). For example, Dondi and his colleagues (1999) showed that newborns cry to the distress sounds of another infant yet they do not cry while listening to their own cries. Findings like these have led researchers to propose an evolutionary basis for empathy (Hoffman, 2000). Detecting an emotion in a peer, and the autonomic and neurophysiological responses that seem to mimic the physiology of the distressed object are speculated to signal a biological preparedness for emotions and ultimately a physiological substrate for empathy.

### 13.4.3 Heritability

Some investigators have demonstrated a potential genetic basis for empathy (Hoffman, 2000). For example, Zahn-Waxler *et al.* (1992) found modest evidence for heritability of empathy and prosocial behaviours in 14- to 20-month-old monozygotic and dizygotic twins.

Further, empathic reasoning was associated with fewer behavioural problems in twin studies, suggesting a possible genetic basis for risk and resilience for psychopathology (Zahn-Waxler *et al.*, 1996). Ultimately, these findings have been used to suggest that empathy has genetic influences as well as environmental ones (due to the modest heritability factor) during normal and problematic development.

### 13.4.4 Individual contributions and temperament

Autonomic and neural functioning have been linked to the development of empathy, thus it is highly plausible that individual differences in neural system function support or inhibit its development (Jones *et al.*, 1998, 2000). As we will see more in depth in the next section, coordinated activity between a caregiver and an infant is required for adaptive regulation of emotions, a process that leads to empathic competence across the lifespan. As with any relationship, both individuals bring their unique temperament and biological inclinations to the equation. Thus individual contributions can set the tone for future interactions in that relationship.

One method of evaluating individual differences in social interactions and response styles to social events is with the use of autonomic nervous system measures, which have been associated with neurological development and empathy. Moreover, developmental studies have shown consistent patterns of heart rate responding related to empathic behaviours. In a number of studies (Zahn-Waxler *et al.*, 1995), a link between heart rate deceleration and empathy has been supported. The data suggest that heart rate deceleration may be an index of other-oriented attention and thus an index of empathy, whereas heart rate acceleration may be an index of self-oriented attention and thus an index of anxiety or fear. For instance, Zahn-Waxler and her colleagues (1995) tested children at risk for externalizing problems and determined that heart rate deceleration during an empathy-inducing stimulus (and higher heart rate at baseline) predicted empathic concern and prosocial behaviours. In addition, lower tonic heart rate (i.e. baseline) was associated with aggression and avoidance, behaviours that inhibit empathic responding.

Although studies have established a link between individual differences in hemispheric specialization and emotional responsiveness (Davidson, 2004; Fox, 1991), in only a few studies have we examined the relationship between empathy and brain electrical activity patterns in: (1) children of depressed mothers compared to psychologically healthy controls and (2) children who were prenatally exposed to cocaine compared to an unexposed, demographically matched control group (Jones *et al.*, 1998, 2000). Across several studies, our findings suggest that greater relative right frontal asymmetry and lack of empathic behaviours are present in children of depressed mothers and children prenatally exposed to cocaine, with both groups showing greater right and left hemispheric activity (with the right hemisphere activity more pronounced) in the frontal region. Right frontal asymmetry has been implicated in negative moods and inhibited temperament, suggesting individual differences in biobehavioural risk factors for these children. Lack of empathy was associated with maternal-reported anxiety, conduct problems, hyperactivity and impulsive behaviours in children of depressed mothers and in children who were cocaine-exposed during gestation. These later findings, although based on a potentially biased maternal report, could affect caregiver–child interactions across development and could have an effect on the development of neural processes. Although inconclusive, these data should be used to provide a spring board for further studies on the development of empathy, cognitive abilities, social skillfulness, and neurophysiological changes, as these areas are most influenced by neural plasticity during development.

### 13.4.5 In adults

Studies examining the neurophysiology of empathy in healthy adults are scarce, as most studies focus on understanding simple emotions or emotion-linked traits in adults (Davidson, 2004; Tomarken *et al.*, 1990). Nonetheless, the research in existence, to date, indicates that empathy may be a personality trait that has a neurophysiological basis. For example, Levenson and Ruef (1992) examined the physiological responses of adults watching a marital interaction and found that perceptions of another's emotions were most accurate when the observer matched the object's physiological state for negative emotions. For positive emotions, accuracy was correlated to lower cardiovascular arousal in the observer. This finding lends some support to the theories of 'mirror neurones' through which individual's matched physiology supports the ability to subjectively represent what another is feeling (Gallese, 2003). These theories are intriguing, albeit in need of further elucidation with empirical evidence.

Neurophysiological studies of emotions suggest that positive, approach-oriented emotions and individual differences in personality traits are related to neurophysiological activity in consistent ways (Tomarken *et al.*, 1990). Specifically approach-related emotions and tendencies are associated with the left frontal regions of the brain. Recently, studies (Urry *et al.*, 2004) have even demonstrated that eudemonic emotions (i.e. those emotions related to feelings of well-being stemming from an orientation toward inner happiness and life-purpose) are associated with left frontal EEG asymmetry. Similarly other studies have suggested that depressive symptoms are associated with right frontal EEG asymmetry due to left frontal hypoactivation.

In summary, human infant, child and adult studies have associated the neurophysiological activation of brain areas with emotions, yet these associations with empathy are an understudied area of research. Only a handful of studies have suggested that empathy may be a process carried out by the left frontal regions of the brain. Understanding the progression of empathy in the brain would inform both scientific and clinical endeavours. Thus, future research should investigate these issues more fully, especially during the stages of plasticity in development.

## 13.5 Dysfunctional socialization experiences and changes in brain activation and empathic responding

It is now well established in the literature that personality traits are most often the result of the interplay between genetic endowment and developmental milieu. Cerebral functioning has a much greater impact on adaptive socioemotional functioning than previously thought and, conversely, the socioemotional environment has a determinative effect on the development and proper functioning of the human brain. In other words, sequential, normal neurodevelopment is dependent on the environmental conditions and circumstances of each child (Glaser, 2000) particularly in utero and during the formative first few years of life.

During the first few years of life, the infant's neural network is more malleable than at any other time during the lifespan (Bell, 1998). Accordingly, this critical period of brain development provides tremendous opportunity for the development of adaptive functions while at the same time making the infant enormously vulnerable to the impact of environments that either inhibit growth or fail to provide the input needed for optimal growth. The frontal lobes' period of plasticity specifically extends into the second year of life (Fox *et al.*, 1994). Thus, if appropriate environmental input is not provided, or, if inappropriate stimuli are introduced in early childhood, executive functions under frontal lobe control, such as emotion regulation and empathy, will miss their opportunity for normal development, leaving the growing child with a functional deficit that will not easily be ameliorated later.

There are two general ways in which environment affects brain development. Some growth is experience-expectant, meaning that pre-programmed neurodevelopmental sequences are triggered by experiences that are reasonably expected to happen during the course of normal development. Other processes of brain development are referred to as experience-dependent, in that neural structures are not necessarily anticipating certain experiences, but are highly receptive to them (Greenough & Black, 1992). Unlike experience-expectant development, which sets off genetically predetermined synaptic growth, experience-dependent development provides the opportunity for creation of new synaptic connections as a response and consequence of environmentally based experiences (Bell & Fox, 1994; Glaser, 2000). The maturation of the orbito-frontal system is primarily experience-dependent, with empathic ability developing only if it is adaptive within the context of the young child's limited environment, which often consists primarily of the attachment figures. The absence of appropriate learning experiences can lead to changes in the functional organization of the brain; synaptic connections will form (or fail to form) in accordance with the information the child receives from his/her environment (Bell & Fox, 1994). The neural pathways that remain, for better or for worse, will become the foundation of the child's emotional capabilities (Courchesne *et al.*, 1994).

Responsive, affectionate caregiving facilitates bonding and attachment, and it is within that context that the infant's brain develops the capacity for more elaborated emotional regulation and empathic social interactions. The sight of a responsive mother's face triggers the release of high levels of endogenous opiates in the child (Hofer, 1994), thus forming an association between social reciprocity and pleasure. Furthermore, an attuned mother–child dyad will develop an emotional transaction 'rhythm' (Jaffe *et al.*, 2001) that fosters the growth of neural pathways for emotion regulation in the child (Fox *et al.*, 1994).

Human offspring are instinctively drawn to their social environment and to their caregivers to reduce emotional discomfort and to be restored to a more balanced state. Then, based on the caregiver's pattern of responses, the child develops a working model of the world. Stated differently, not only does the attuned, attentive caregiver provide the child with the building blocks of affect regulation, but also teaches the child that he/she can expect affectionate treatment from others. Attuned mother–infant dyads are engaged in a dance, a form of non-verbal rhythmic communication in which each partner both affects and reflects the emotional state of the other (Fogel & Bramco, 1997). During this physiological and behavioural dance, the partners synchronize and mirror each other's psychophysiology and amplify each other's positive affective states creating a synergistic effect. It is within these types of interactions that the capacity for empathy develops.

As such, a caregiving relationship that is characterized by abuse or neglect impedes the development of empathy (Glaser, 2000). Harmful or neglectful caregiving leads to an alteration of the neural system, hence a disruption of proper emotion-processing functions (Schore, 1996) that perpetuates into adulthood (Glaser, 2000). Studies have revealed left fronto-temporal EEG abnormalities in paediatric psychiatric inpatients (Ito *et al.*, 1998) and limbic system dysfunctions in adult psychiatric outpatients with histories of abuse (Teicher *et al.*, 1993).

In the context of abuse, empathy is not adaptive so the abused child develops only a limited capacity for it. Caregiving by an abusive mother encourages a dissociative response in the child (Schore, 1996). The unregulated affect of the mother (in addition to the infant's own unregulated affect) overwhelms the child's capacity to cope, and the infant defensively disconnects from interaction. In the case of a non-attentive mother, the child disconnects from the interaction to reciprocate the mother's state. For instance in laboratory experiments, children of depressed mothers, which often translates into emotional deprivation or insensitive-intrusive caregiving, responded less empathically than normal controls (Jones *et al.*, 1997, 2000).

Animal studies shed additional light on the effects of early maternal deprivation on brain development. In experiments, animal infants deprived of normal maternal interaction have stress reactions resulting in cerebral cell death (Plotsky & Meaney, 1993). In humans, stress enhances the release of dopamine in the prefrontal cortex, which, along with noradrenaline (Charney *et al.*, 1993) and elevated cortisol levels (Gunnar, 1998), is associated with dysfunction of the frontal regions of the brain (Arnsten, 1999). In fact, our own studies have shown that maternal biochemical stress levels can negatively affect the growth and psychobiological development of neonates (Lundy *et al.*, 1999).

In sum, early environmental experiences have lasting socioemotional consequences and may alter an individual's developmental path altogether. While neuropsychobiological studies on traumatized infants and young children are scarce (with no psychophysiological studies on this topic that we know of), and may not yet account for individual variation in adaptation among abused and neglected children, the totality of the evidence thus far points us in the direction that early socialization is critical to the development of empathy and much of this process involves shared and changed physiology.

## 13.6 Frontal lobe dysfunction and consequences for empathic responding

Thus far, research on the physiology of emotions leads us to conclude that empathy is mostly a function of the fronto-orbital cortexes and the limbic system. It follows then, that disruption of frontal lobe functioning would impair an individual's ability to be socially adaptive. Indeed, the literature supports that assumption. In this section, we will examine how dysfunction in the frontal lobes, whether from developmental abnormality, traumatic injury, or disease, can result in lack of empathic abilities and psychopathology.

A handful of DSM-IV (American Psychiatric Association, 1994) disorders are characterized by empathy deficits. In children, they include autism spectrum disorders (autistic disorder, Asperger's disorder, and other pervasive developmental disorders) and disruptive behaviour disorders (attention deficit-hyperactivity disorder, conduct disorder and oppositional defiant disorder). In adults, these include antisocial personality disorder, borderline personality disorder, schizophrenia and factitious disorder by proxy (Appendix B: Criteria Sets and Axes for Further Study). This last disorder however is controversial and both its aetiology and neurophysiological correlates are in need of further scientific inquiry.

The disorder most often linked by the literature to frontal lobe dysfunction is antisocial personality disorder (ASPD) (Damasio *et al.*, 1990). A number of studies have evaluated post-morbid behaviour in individuals who sustained damage to the frontal lobes from traumatic injury and/or brain disease (Grattan & Eslinger, 1989; Shamay-Tsoory *et al.*, 2003). Collectively, these studies have found that previously high functioning, sociable individuals now exhibited enough psychosocial maladaption to meet diagnosis criteria for ASPD. Physiologically, these individuals exhibited hypoactivation of somatic states, as indicated by attenuated skin conductance responses when presented with socially meaningful, empathy-inducing stimuli (Damasio *et al.*, 1990).

In addition to ASPD, frontal lobe dysfunction may play a role in the development of borderline personality disorder (BPD). In support of this hypothesis, Völlm and his colleagues (2004) found that both ASPD and BPD patients activated more widespread prefrontal and temporal areas than healthy controls in a response inhibition task. This result can be interpreted as indicating that ASPD and BPD patients need to recruit additional resources to compensate for frontal lobe dysfunction. This interpretation is consistent with Raine's (Raine *et al.*, 2000) finding that individuals with ASPD have 11% less prefrontal grey matter than healthy controls, and with other findings that individuals with BPD have smaller frontal lobe volumes (Lyoo *et al.*, 1998).

Similarly, with childhood disorders, specifically with autistic disorder 'often an individual's awareness of others is markedly impaired. Individuals with this disorder may be oblivious to other children [. . .], may have no concept of the needs of others, or may not notice another person's distress' (DSM-IV, p. 66). This latter feature describes the observed lack of empathy in autistic children. In fact, Blair (1999) found that when children with autism are encouraged to focus their attention on another person's distress they simultaneously exhibit greater skin conductance responses. Yet, despite this autonomic arousal, they fail to respond behaviourally. A likely explanation is that individuals with autism have difficulty with the cognitive appraisal of what they are witnessing, fail to understand its social meaning, and thus fail to respond behaviourally. Researchers have speculated that the cerebello-frontal pathway may be involved in autism (Dawson, 1996). It is likely that a disruption in frontal lobe functioning accounts for the observed empathy deficits in this disorder.

Research on frontal lobe involvement in empathy deficits of children with disruptive behaviour disorders, on the other hand, is much more inconclusive, and even sometimes contradictory. For instance, while PET studies found reduced metabolism in frontal regions of ADHD children (Amen & Carmichael, 1997), other studies found no clear differences between ADHD and control children in heart rate and skin conductance (Zahn-Waxler *et al.*, 1995).

In summary, while frontal lobe dysfunction appears to play a critical role in the development of certain psychopathologies, much of the evidence is inconclusive and in need of both replication and novel research designs. Additionally, it may be useful, as we move forward with the exploration of disorders associated with empathy deficits, to distinguish between those that also involve malevolence, such as psychopathy, and those that are of a more benign (although important) quality, such as autism. While they may both have neurophysiological substrates in common, they are indeed qualitatively different. At this point in time, however, the exact neurophysiology of any empathy deficits remains a mystery. Nonetheless, the technological advances in brain mapping and the re-emergence of data and research interest in the phenomenon of empathy are promising.

## 13.7 Summary

Empathy is a necessary component of positive human social relationships, which, in turn, undergird mental health. As methods of scientific inquiry improve and technology provides us with increasingly useful tools, our knowledge and understanding of human social emotions expand. Evolving understanding of the neurophysiological systems has supported the association between frontal lobe functioning and empathy. Specifically frontal areas have been shown to have a prominent role in influencing empathic responding. Additionally, multiple areas of the brain are involved in empathy at different levels of processing, including limbic and temporal, as well as autonomic nervous system functions. The plasticity of the human brain, particularly the frontal lobes, in the early years of life provides if not a blank slate, an easily modifiable slate for environment to write on. Thus, an individual's experiences within their environment provide the conditions for neural predispositions to express themselves. During this sensitive period, the growing child's world consists almost entirely of the primary caregiver. This relationship teaches the child about human social interaction (via maternal behaviour) and self-regulation of emotional arousal (via psychobiological attunement). Healthy early relationships are essential to optimal neural development, which in turn is critical for the development of empathy. In sum, it appears that empathy involves multiple brain regions and that individual variation in environmental experiences can modify neurophysiology, resulting potentially in deficits in empathic processes.

Dysfunctions in the fronto-orbital cortex and the limbic system are believed to reduce the individual's capacity for empathic responding and can lead to social impairment and psychopathology. Individuals with psychological and neurological disorders that are characterized by empathy deficits have neuroimaging patterns and physiological responses that differ from those of healthy individuals. While research on frontal lobe functioning in the context of empathic abilities is still in its infancy, the findings to date suggest this will likely be a fruitful avenue for expanding our knowledge of the neurophysiological substrates of empathy.

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