Chapter 4

THE PSYCHOPHYSIOLOGICAL MEASUREMENT OF EMPATHY

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ABSTRACT

Empathy is a multifaceted construct that has traditionally been studied using self-report measures. The field of psychophysiology is increasingly offering additional measurement techniques to objectively record changes associated with empathy in the central and autonomic nervous system. The present chapter will review what can be gained by studying empathy using psychophysiological methods such as neuroimaging, electroencephalogram (EEG), facial electromyographic activity (EMG), startle blink reflexes, skin conductance responding, and heart rate. These psychophysiological measurements are particularly well suited to studying (a) the mimicry of facial expressions, (b) emotional contagion and the mirror neuron system, (c) correlates between nervous system changes and self-report measures of empathy, and (d) empathy in special populations. Moreover, psychophysiological measures may offer more objectivity than self-report measures and can be used in individuals for whom self-report measures may be unreliable or unsuitable (e.g., children). Future research using a multi-method approach combining self-report, behavioural, and psychophysiological measurements has the potential to significantly broaden and advance our understanding of empathy.

INTRODUCTION

Despite the frequently noted difficulty of defining empathy (e.g., Batson, 2009), contemporary conceptualizations recognize empathy's relation to central and peripheral nervous system activity (Decety and Ickes, 2009). Nervous system activity will determine the affective intensity and cognitive accuracy associated with interpreting social situations (Ickes,

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Stinson, Bissonette, and Garcia, 1990) and, by consequence, influence the behavioural outcomes of empathic experiences. Traditionally, empathy has been studied using self-report and behavioural measures, and those studies have provided a wealth of knowledge. Increasingly, psychophysiological methodology's examination of the links between nervous system activity and empathy is adding to this knowledge. Psychophysiological measures not only provide new insights, but also give methodological tools otherwise not possible with past research approaches.

Based on definitions of the field of psychophysiology (Cacioppo, Tassinary, and Bernston, 2007), a psychophysiological approach to studying empathy aims to understand the behaviours and experiences associated with empathy. This psychophysiological approach to studying empathy is distinct from psychology more generally in that physiological constructs and processes are an explicit and integral component in its theory and investigative methods. Additionally, it is distinct from behavioural neuroscience in that it has greater focus on how higher order cognitive and affective processes may relate to both central and peripheral nervous system processes associated with empathy. A psychophysiological approach is complementary, not in opposition, to other psychological and neuroscientific approaches that study empathy. A variety of methodological approaches can only broaden our understanding of such a complex and multifaceted construct as empathy, although some may provide advantages over others.

In addition to linking empathy to nervous system activity, a psychophysiological approach has the potential to offer a level of objectivity that may not be present with other measures, such as self-report scales. It has been argued that self-report measures can have less than ideal reliability (Chlopin, McCain, Carbonell, and Hagan, 1988); have low validity (as shown by inconsistent relationships with external criteria); and as a group, have low inter-correlations (Eisenberg and Lennon, 1983; Levenson and Ruef, 1992). The accuracy of self-reports is limited by human perception errors. Social desirability may also influence the truthfulness of the reports (Duan and Hill, 1996). Kämpfe, Penzhorn, Schikora, Dünzl, and Schneidenbach (2009) found that, on a self-report measure, delinquent participants reported higher empathy (cognitive concern) than non-delinquent control participants. However, this difference was partly explained by the higher social desirability in the delinquent participants. Using an indirect measure, it was found that empathy was actually higher in non-delinquent participants than in delinquent participants. Findings such as these highlight the necessity of caution when using self-report measures of empathy. Conclusions can be stronger when multiple, methodologically distinct operational definitions of a construct are used (Nisbitt and Wilson, 1977).

The present chapter aims to give an overview of the psychophysiological approach to studying empathy. Following a discussion of the definition of empathy, a short description of the main psychophysiological measures used in research on empathy will be provided. The contributions that a psychophysiological approach has made to understanding empathy will be discussed. Then, the discussion will be framed by the approaches used by researchers and what particular aspect of empathy has been the main focus in the work. Through this review it is hoped to show that a psychophysiological approach can offer significant insights into the nature of empathy and its practical applications in promoting caring and prosocial behaviours towards others.

EMPATHY

Empathy is a multidimensional construct that has been difficult to define. The word 'empathy' comes from the German word 'einfuhlung' used to describe the way people willfully project themselves into a work of art to aesthetically appreciate its qualities. Titchener (1909) used the term in a different way, to describe how people may objectively enter into the experience of another in order to gain a deeper appreciation of their feelings and thoughts. Batson (2009) identified eight diverse, but related, conceptualizations of empathy (see also, Reik, 1948; Scheler, 1913/1970). These conceptualizations were (a) knowing another person's cognitive and affective internal state, (b) adopting the posture or matching the neural response of another, (c) feeling as another person feels, (d) projecting oneself into another's situation, (e) imagining the thoughts and feelings of another, (f) imagining how one would think and feel in the other's place, (g) feeling distress at witnessing another's suffering, and (h) feeling for another person who is suffering. A psychophysiological approach would be more appropriate for adopting some of these conceptualisations than for others. For example, conceptualizations (b), (c), (g), and (h) seem to be particularly amenable to psychophysiological investigation.

The comprehensive model of empathy termed the Perception-Action Model (PAM) as proposed by Preston and de Waal (2002), contains many of the elements in conceptualisations (a) to (c) (Batson, 2009). It has also been adopted as a framework when interpreting the results in many psychophysiological studies on empathy (e.g., Bufalari, Aprile, Avenanti, Di Russo, and Aglioti, 2007; Han, Fan, and Mao, 2008; Jackson, Brunet, Meltzoff, and Decety, 2006). In the PAM, the perception of another person's state (the 'target') will automatically activate representations in the individual relevant to the state, situation, and target and will prime the associated autonomic and somatic responses (Preston and de Waal, 2002). Therefore, individuals who pay attention to empathy-eliciting stimuli should show a range of autonomic and somatic responses consistent with their interpretation of the target's affective state. The empathic process can be disrupted, augmented, or over-ridden by processes which may result from empathic responding, such as perceptions of fairness or behavioural avoidance.

The PAM encompasses basic motor and emotion categories of behaviour within the superordinate perception-action mechanism (Preston and de Waal, 2002). In this model, empathy is facilitated by behaviours that rely on perception-action mechanisms such as motor mimicry and imitation, the Simon effect, ideo-motor behaviours, and response preparation. Moreover, the PAM describes the affective components of empathy as proximal and immediate, involving feelings generated on a visceral, physiological dimension. These affective components are based on the premise that empathic responding stems from neural representations that are automatically and unconsciously activated in the observer that are similar to those perceived in the observed target (de Waal, 2008) such as can be seen in the phenomenon of emotional contagion. These aspects of the PAM give a good platform from which to operationalise empathy-related responding via the objective measurement of central, autonomic, and motor system activity. Complementing these processes is the less-emotional and cognitive component of empathy, construed as arising from an ultimate level of causality, involving perceived outcomes of responses to others feelings. These components are usually measured by the administration of self-report measures.

PSYCHOPHYSIOLOGICAL MEASURES

The range of possible psychophysiological measurement techniques available to study empathy is extensive. Empathy research has largely taken advantage of some measures (e.g., neuroimgaging, electroencephalography, facial electromyography) more than others (e.g., eye movements, eye blinks, blood pressure, and blood volume). Those measures that are more extensively used may be grouped according to whether they are based on the central nervous system (e.g., neuroimaging, electroencephalography), motor system (e.g., facial electromyography, startle blinks), or peripheral nervous system (e.g., electrodermal activity, heart rate). Detailed descriptions of the full range of psychophysiological measures can be found in Andreassi (2007) and Cacioppo, Tassinary, and Bernston (2007).

Neuroimaging

Neuroimaging techniques can provide precise information about the spatial localization of the brain structures involved in empathy (for reviews, see Decety and Lamm, 2006; Farrow, 2007; Shirtcliff et al., 2009). The use of neuroimaging methods requires specialised and costly equipment as well as technical staff to run the machines and to use computers to process the massive amounts of data that are generated. These factors can limit the availability of the technology to researchers. Functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) have been the main types of neuroimaging approaches used to quantify the brain activity assumed to be associated with empathy. Both examine neural activity by measuring hemodynamic changes caused by variations in blood oxygen concentration and blood flow. The hemodynamic changes provide an indirect measure of neural activity based on the assumption that changes are correlated in time and space with neural activity.

The fMRI measures hemodynamic changes by applying a radio frequency pulse to an individual placed in a strong magnetic field. High resolution images of the level of activity in neural structures can be achieved through sophisticated data acquisition methods. The BOLD fMRI, for example, indexes neural activity by measuring the blood oxygen level dependency of active neurons. The fMRI temporal resolution is 500 to 1000 ms and the spatial resolution is often about 2 mm. The PET method requires the individual to be injected with a radioactively labeled glucose to indirectly detect changes in the metabolic state of neurons. The assumption again is that more active neurons will require more glucose and oxygenated blood. PET scans generally have less spatial resolution to fMRI scans of about 3 to 5 mm. A PET scan also generally takes longer than an fMRI scan and is more invasive due to the need to inject the radioactive substance.

Electroencephalogram

The electroencephalogram (EEG) is a recording of the firing of the neurons through the placement of electrodes along the surface of the scalp. A monopolar or a bipolar recording technique may be used (Andreassi, 2007). The monopolar method, for example, uses a single

active electrode over the area of interest (e.g., visual cortex) and a reference electrode placed in a relatively inactive area (e.g., earlobe). The specific locations that electrodes may be placed are defined in relation to the 10-20 System along areas described as frontal (F), central (C), parietal (P), occipital (O), and temporal (T) and in relation to the individual's head size. Simultaneous recordings from either 32, 64, 128, or 256 electrode locations are common when using prearranged electrode caps. Recordings of eye blinks are also taken because they can interfere with an EEG.

The EEG produces different brain wave patterns depending on the state of the individual. Different types of waves have been characterized according to the frequency band in which they are found. These include alpha (8 to 13 Hz), beta (14 to 30 Hz), gamma (30 to 100+ Hz), theta (4 to 7 Hz), and delta (0.5 to 3.5 Hz). Each of the waves can indicate the individual's state and any changes in state. For example, alpha waves are produced when an individual is sitting quietly with eyes closed. Once the individual does a cognitive task, the alpha waves will become smaller or may disappear. Short-term changes in the EEG can be elicited by stimulus events and these are termed event-related potentials (ERPs). ERPs are defined in relation to whether the wave is positive or negative and the latency (in ms) of the change. For example, the P300 is a positive change that occurs at 300 ms following the stimulus onset. As these short timeframes indicate, the EEG has excellent temporal resolution. The combination of neuroimaging (good spatial resolution with poorer temporal resolution) with EEG (good temporal resolution with poorer spatial resolution) provides complementary methodology to investigate the central nervous system correlates of empathy.

Facial Electromyographic Activity

Electromyography (EMG) is the measurement of the electric potentials that occur when muscle fibres contract. The EMG can be recorded through electrodes placed on the skin over the site of the muscle of interest. On the face, these muscles include the *corrugator supercilli, zygmaticus major, lateral frontalis, medial frontalis, levator labii superioris, orbicularis oculi*, and *masseter*. Facial muscles are particularly relevant for empathy research because of their association with the expression of facial emotions (Darwin, 1890/2009; Dimberg, 1990). For example, the corrugator knits the brow and is contracted during frowning. Increased activity in the corrugator is thus indicative of negative expressions. The zygomaticus pulls the lip corner back and is contracted during smiling and can thus be associated with positive expressions. The levator raises the upper lip and widens the nostrils and thus can be contracted when expressing disgust. The magnitude of the EMG signal increases when the muscle fiber units contract and is typically the dependent variable in research. An advantage of using EMG is that this technique is able to detect facial muscle activity below the visual threshold, thus making it a more sensitive and objective measure than observer ratings of facial expression used in some research.

Startle Blink Reflexes

The startle blink reflex is a component of the more generalized startle response. It can be elicited by an abrupt and moderately intense stimulus. For example, a white noise burst

presented for 50 ms and an intensity of 110 dB(A) can be used (Neumann and Lipp, 2003). To measure the blink reflex, EMG recordings of the muscle that controls blinking, the *orbicularis oculi*, are made. The blink magnitude is usually measured, although other parameters such as blink latency or area under the curve may be measured. Blink magnitude has been shown to be sensitive to attention and emotion (Bradley and Lang, 2007) and as such it may be used to examine the nature of empathy. The most important aspect of startle blink methodology is that the startling stimulus is used as a probe. As such, it is presented at a discrete time period (termed a lead interval) following the onset of a stimulus to probe the ongoing cognitive and affective processes of the individual. For example, when using stimuli from the Pictures of Facial Affect set, the startle reflex is potentiated when elicited during faces showing negative expressions (fearful and angry) but can be reduced in magnitude during faces showing positive expressions (Anokhin and Golosheykin, 2010). These results may be interpreted as reflecting the match or mismatch in valence between the pictures and the startle probe (see Bradley and Lang, 2007 for a discussion).

Electrodermal Activity

Electrodermal activity refers to a group of measures that are sensitive to changes in the electrical activity of the skin (Andreassi, 2007). The most common of these measures in contemporary research is skin conductance, which measures the changes in skin conductivity to an externally applied current. The conductivity will change according to the activity of the eccrine sweat glands in the skin. For this reason, skin conductance is typically measured from sites on the skin where these sweat glands are most concentrated (e.g., palm of the hands and fingertips). The eccrine sweat glands are under the control of the sympathetic nervous system, which means that skin conductance responses give an indication of activation related to non-specific visceral affective arousal.

Two types of electrodermal activity may be distinguished. Tonic measures (e.g., skin conductance level) are derived from the level of electrodermal activity and they reflect longer-term changes in sympathetic nervous system activity. Phasic measures (e.g., skin conductance responses) are superimposed on these and are short-term changes in response to internal or external events. When used in empathy research, these measurements can provide an index of the degree of emotional responsiveness and attentional engagement of participants to empathy-eliciting stimuli. Skin conductance responses are sensitive to orienting, sustained attention, stimulus significance, and the affective intensity of a stimulus, among other psychological phenomena (Andreassi, 2007). The sensitivity to such a wide range of psychological states also means that it is a somewhat nonspecific response. The extent to which these changes reflect more specific psychological states related to empathy needs to be inferred from the types of stimuli presented in an experiment and how they relate to other measurements (e.g., heart rate).

Cardiovascular Activity

Cardiovascular activity is sensitive to both affective and attentional states, (Adreassi, 2007) suggesting that this measure may be sensitive to various aspects of the empathic

response. Cardiovascular activity may be recorded from the electrocardiogram (ECG) or through transducers (e.g., a piezoelectric transducer). Like electrodermal activity, measures of cardiovascular activity may be grouped broadly as tonic or phasic. Example: tonic measures include mean heart rate and heart rate variability over a session. Phasic changes reflect the short term acceleration and decelerations in heart rate that occur in response to stimulus events. Although these tonic and phasic measures are most commonly used, other measurements such as T-wave amplitude or total peripheral distance may also be derived from the ECG. Cardiovascular activity in empathy research may have been under utilised so far, since there is some indication in the literature that heart rate acceleration and deceleration may be able to discriminate between appetitive and defensive responding. This differentiation may have important implications for the interpretation of emotional responses in the context of empathy research.

PSYCHOPHYSIOLOGICAL STUDIES OF EMPATHY

The relevance of psychophysiological measures to studying empathy has been known for some time, even though there has only been a dramatic increase in research in recent years. For example, Krebs (1975) examined skin conductance, heart rate, and blood pulse volume in participants that observed a target play a roulette game. Participants were led to believe that the target won money or experienced pain according to wins and losses in the game or that the target was merely doing a cognitive task. Those participants that were told that the target gained pleasure (won money) or experienced pain during the game showed larger physiological reactions than participants that were not given those instructions. Moreover, the psychophysiological responses were augmented in participants who believed they were similar to the target and identified with them. The results were interpreted as reflecting that participants empathised with the target when they experienced pleasure and pain.

In another example, Levenson and Reuf (1992) used heart rate, skin conductance level, general somatic activity, pulse transmission time to finger, and finger pulse amplitude to examine emotional contagion in married couples. Correlations between physiological recordings and ratings of affect showed that the greater the congruency in physiological responses between the spouses, the greater the accuracy of rating the other spouse's negative affect. These findings suggest the significance of shared physiology, or physiological linkage, in the empathic response and its accuracy.

The early studies by Krebs (1975), Levenson and Reuf (1992), and others showed that using psychophysiological methods can contribute to our understanding of empathy. In subsequent work, researchers have examined empathy by employing concepts such as emotional contagion, mimicry, and mirror neurons. Correlations between psychophysiological measures and self-report ratings of empathy have also been examined. Finally, researchers have evaluated special populations for which empathy may be different and these findings can be related back to our understanding of empathy in normal populations (e.g., Iacono, 1991; McIntosh, Reichmann-Decker, Winkielman, and Wilbarger, 2006).

Emotional Contagion to Socially Relevant Stimuli

Emotional contagion refers to the tendency for people to mimic or synchronise their facial expressions, postures, and vocalizations with those of another person (Hatfield, Cacioppo, and Rapson, 1994). Hatfield, Rapson, and Le (2009) suggested three possible mechanisms by which emotional contagion can bring people to understand what others are feeling: the activation of feedback; mimicry; and contagion of emotion. Due to their nature, psychophysiological methods have been particularly useful in shedding light on these mechanisms, particularly the latter two.

Mimicry

Mimicry refers to the tendency for people to show the same expressions as those of the target they are interacting with or observing. In an early report by Lipps (1903), it was proposed that people tend to mimic the facial, vocal, or postural expressions of emotions shown by others and that such mimicry will evoke the corresponding emotions in the observer. Many researchers currently consider motor mimicry as vital to emotional empathy, and possibly even biologically 'hardwired' (Hatfield et al., 1994; Hoffman, 2002; Meltzoff and Decety, 2003; Preston and de Waal, 2002). In investigating mimicry, recordings of facial EMG have proven to be extremely useful. The measurement of dynamic and changing facial expressions during the course of an interaction may imply a limitation for the accurate examination of mimicry. However, facial EMG research shows that mimicry occurs to static displays of angry and happy facial expressions in a similar way to dynamic video displays (Fujimura, Sato, and Suzuki, 2010). Static stimuli thus provide a stable format for assessing mimicry. Facial EMG research shows that mimicry can be spontaneous and rapid (Dimberg and Thunberg, 1998) and when combined with EEG or neuroimaging it has given unique insights into the determinants of emotional responses, including their neural correlates (Achaibou, Pourtois, Schwartz, and Vuilleumier, 2008).

The corrugator and zygomatic muscles have been most extensively used to examine mimicry of facial expressions. The corrugator reacts to a variety of negative facial expressions, such as angry faces (e.g., Dimberg and Thunberg, 1998; Fujimura et al., 2010). However, corrugator activity can also be elicited by non-facial visual stimuli or even sounds and words (Larsen, Norris, and Cacioppo, 2003). Thus, the mere activation of the corrugator muscles may not necessarily be taken as a measure of mimicry in all situations. Zygomatic activity is enhanced when viewing facial expressions showing happiness, smiling, and laughter (Achaibou et al., 2008; Fijimura et al., 2010). Zygomatic activity is enhanced during high arousal pleasant conditions, although this arousal effect does not appear to hold for courrugator activity during unpleasant conditions. (Fijimura et al., 2010). Facial EMG reactions are: rapidly evoked (i.e., under 400 ms; Dimberg and Thunberg, 1998); present when subjects are unconsciously exposed to facial stimuli (Dimberg, Thunberg, and Elmehed, 2000); and hard to restrain voluntarily (Dimberg, Thunberg, and Grunedal, 2002). Taken together, the facial EMG data are consistent with the notion that facial mimicry is an early, automatic response to others displays of facial emotions.

Our mimicry of facial expressions and other associated psychophysiological responses may also be influenced by the identity of the target. Brown, Bradley, and Lang, (2006)

presented African American and European American participants with pleasant and unpleasant facial expressions of members of the same or different ethnic group. African American participants had larger corrugator EMG responses when viewing unpleasant pictures of Black targets compared to when viewing unpleasant pictures of White targets. This finding suggests an ingroup bias in mimicry of facial expressions. Another finding was that European American participants had larger electrodermal responses when viewing pleasant and unpleasant pictures of White targets than African American participants. Taken together, these results were interpreted as consistent with an ingroup empathy hypothesis (i.e., people will show exaggerated affective responses when viewing pictures depicting ingroup members).

In the context of the PAM (Preston and de Waal, 2002) the findings of Brown et al. (2006) may reflect a similarity effect on empathy. It should be noted that Brown et al. (2006) did not obtain any subjective measures of empathy to test for convergent validity of the interpretation of the psychophysiological results. However, they are comparable to the psychophysiological findings reported by Westbury and Neumann (2008), who examined empathy-related responses to human and non-human animals depicted in negative circumstances. Westbury and Neumann (2008) observed that corrugator activity, skin conductance responses, and empathy ratings increased as the stimuli increased in phylogenetic similarity to humans (i.e., increased from bird, to quadruped mammal, to primate, to humans).

While the prior research is largely consistent with the notion that people show mimicry in response to the facial expressions of targets, further research is needed to understand the neural mechanisms that underlie them. Achaibou et al. (2008) concurrently recorded facial EMG and EEG when participants viewed video clips containing angry or happy facial expressions. As expected, corrugator activity was enhanced during angry video clips and zygomaticus activity was enhanced during happy video clips. Furthermore, right P100 visual evoked potential amplitude was positively correlated with the corrugator and zygomaticus activity during the angry and happy facial expressions, respectively. In contrast, the N170 component was negatively correlated with facial EMG activity. The correlations suggest that neural processes that underlie these early EEG components determine the extent of facial expression mimicry in people and thus subsequent empathic responses to others displaying anger and joy.

Contagion of the Emotion

Contagion refers to the 'catching' of anothers emotion (Hatfield et al., 2009). This process is thought to be facilitated by the firing of neurons in response to affective stimuli, something which has been known to occur since research examined single neuron responses to stimuli in non-human animals (Brothers, 1989). The term 'mirror neurons' refers to neurons that fire both when the individual performs a certain action and when they observe a target perform the same action. Auditory mirror neurons, for example, have been identified that fire both when monkeys perform hand or mouth actions and while they listen to sounds of similar actions (Keysers et al., 2003; Kohler et al., 2002). When socially relevant stimuli are involved, the action of mirror neurons may provide a mechanism by which emotional contagion and empathy can occur (see Wolf, Gales, Shane, and Shane, 2001).

The use of fMRI and PET has been particularly useful to examine the possibility that the mirror neuron system is implicated in empathy. Supporting such a link have been positive associations between scores on 'perspective taking' (a subscale of the empathy measure by Davis, 1983) and the level of activation of a mirror neuron system for auditory stimuli related to motor execution (Gazzola, Aziz-Zadeh, and Keysers, 2006). It has been argued on the basis of fMRI data that there is a right hemisphere mirroring system that plays an important role in emotional empathy (Leslie, Johnson-Frey, and Grafton, 2004). Additional research using PET has shown that the medial and superior frontal gyrus, occipitotemporal cortices, thalamus and the cerebellum are more strongly activated during an empathic response eliciting interview than during a neutral theme interview (Shamay-Tsoory et al., 2005). Research using fMRI has implicated several areas in empathy, including the medial, dorsal medial, ventromedial and ventrolateral prefrontal cortex (Krämer, Mohammadi, Doñamayor, Samii, and Münte, 2010; Lawrence et al., 2006; Seitz et al., 2008), superior temporal sulcus (Kramer et al., 2010), pre-supplementary motor area (Seitz et al., 2008; Lawrence et al., 2006), insula and supramarginal gyrus (Lawrence et al., 2006; Carr, Iacoboni, Dubeau, Mazziotta, and Lenzi, 2003), and amygdala (Carr et al., 2003). Research has also extended some of these findings to children (Pfeifer, Iacoboni, Mazziotta, and Dapretto, 2008) to the examination of sex differences (Schulte-Rüther, Markowitsch, Shah, Fink, and Piefke, 2008), and in-group/out-group perspectives (see Gutsell and Inzlicht, 2010 for a recent study using electroencephalographic oscillations). Taken together, all these results suggest that empathy consists of both affective and cognitive components and hence may involve cortices that mediate simulation of emotional processing and mental state attribution.

Brain activation associated with empathy may differ according to the degree that the situation engages cognitive empathy versus emotional empathy. For example, Nummenmaa, Hirvonen, Parkkola, and Hietanen (2008) asked participants to empathize with a target in photographs depicting people in neutral everyday situations that the researchers argued would induce cognitive empathy or depicting people in situations thought to induce emotional empathy that involved suffering, threat, or harm. When compared to the presumed cognitive empathy eliciting scenes, the emotional empathy eliciting scenes activated areas involved in processing emotion (thalamus) and in face and body perception (fusiform gyrus). Networks involved in mirroring others actions (inferior parietal lobule and premotor cortex) were especially activated by emotional empathy. The authors concluded that emotional empathy elicits somatic, sensory, and motor representation of others' mental states more than cognitive empathy.

Studies using PET suggest that the perspective taken by the participant is another factor that influences outcomes in neuroimaging studies. Ruby and Decety (2004) examined first person and third person perspectives and found that third-person perspectives produced greater activation in the medial part of the superior frontal gyrus, the left superior temporal sulcus, the left temporal pole, the posterior cingulate gyrus, and the right inferior parietal lobe. Greater activity in the postcentral gyrus was detected in a first person versus a third person perspective. Regardless of the perspective taken, the amygdala was activated when processing social emotions. These findings support the notion of a brain network that is important in distinguishing self from others, an important distinction for the study of empathy. In related research, PET scans when viewing social situations and facial expressions from the 'third party' perspective have revealed activation in the right posterior fusiform gyrus and left inferior occipital gyrus, although for the latter it was greater during complex

social situations than for faces (Geday, Gjedde, Boldsen, and Kupers, 2003). As such, these findings are important for understanding the self-other distinction as different from self-focussed or other-focussed attention. The other oriented perspective is most closely aligned with true empathic responses.

Empathy for Pain

Observing another person have a particular experience has been found to activate mirror neurons, and this appears to extend to the perception of pain. Research using fMRI suggests that empathy elicits activity in regions related more to the unpleasant feelings of the pain than to its sensory experience (Singer and Frith, 2005). An early fMRI study by Jackson et al. (2005) shows the basic procedure and main results from this research. Participants were shown photographs of hands and feet in painful situations that were sourced from everyday life occurrences, such as cutting the finger or jamming fingers or hands in doors. The viewing of the painful situations in others was associated with significant activity in the anterior cingulated cortex (ACC), anterior insula, the cerebellum, and to some extent the thalamus. The regions identified in this study are known to play an important role in the affective component of pain processing (Coghill, Sang, Maisog, and Iadarola, 1999; Hofbauer, Rainville, Duncan, and Bushnell, 2001; Ploghaus et al., 1999; Rainville, Duncan, Price, Carrier, and Bushnell, 1997). Participants also made subjective ratings of the amount of pain felt by the person in the photographs. These ratings were significantly correlated with activity in the ACC suggesting that this region has a particular role in the evaluation of pain in others and, possibly, empathy for pain in others.

Further fMRI studies have corroborated the results reported by Jackson et al. (2005) and have extended them to other stimuli or situations. These studies have shown that the perception of pain in others elicits activation of the neural circuit subserving the processing of the affective and motivational dimension of pain, namely the ACC and insula (e.g., Morrisson, Llyod, di Pellegrino, and Roberts, 2004; Price, 2000; Singer et al., 2004, 2006). These results have also been extended in efforts to evaluate empathy. For example, activation in the ACC and anterior insula is positively correlated with empathy scores (Singer et al., 2004). Children (7 to 12 years) who viewed animated images showing painful situations showed increased activity in the insula, somatosensory cortex, anterior midcingulate cortex, periaqueductal gray, and supplementarymotor area (Decety, Michalska, and Akitsuki, 2008). Finally, activity in the brain regions may be influenced by an individual's interpretation of the fairness of the situation (Singer et al., 2006).

There is also evidence that neural responses to others in pain are mediated by similarity or familiarity with the target. In an fMRI study, Xu, Zuo, Wang, and Han (2009) found that when participants viewed faces receiving a painful injection, activity of the ACC and inferior/insular cortex increased in Chinese and Caucasian participants, consistent with previous research (e.g., Jackson et al., 2005; Singer et al., 2004). However, less neural activity in these areas was found when participants viewed videos of other races in pain. In another study, African-American individuals showed augmented activity in the medial prefrontal cortex when viewing the suffering of members of their same racial group (Mathur, Harada, Lipke, and Chiao, 2010). The neural activity in the medial prefrontal cortex was also predictive of greater empathy and altruism towards members of the same racial group.

Researchers have also used other psychophysiological methods to extend the findings from neuroimaging studies. Using somatosensory-evoked potentials, Bufalari et al. (2007) showed that pain stimuli delivered to others increases the amplitude of the P45 somatosensory-evoked potential that reflects the activity of the primary somatosensory cortex. Transcranial magnetic stimulation (TMS) studies have also shown that watching a needle prick a specific muscle in the hand will reduce the corticospinal excitability of the same muscle in the observer (Avenanti, Sirigu, and Aglioti, 2010). Changes in the primary somatosensory cortex elicited by the perception of pain in others have been observed through the measurement of EEG mu suppression, which has been consistently observed over the primary sensorimotor cortex (Cheng, Yang, Lin, Lee, and Decety, 2008). The changes in mu suppression when watching pain situations may also differ between the sexes (Yang, Decety, Lee, Chen, and Cheng, 2009).

Lamm, Porges, Cacioppo, and Decety (2008) asked participants to view targets undergoing painful sonar (auditory) treatment while taking the perspective of either the other person or the self. Recordings from the *orbicularis oculi*, which control tightening of the orbit during wincing, matched the target's expression only in the self perspective condition. Activity of this muscle also correlated with self-report perspective taking scores and marginally so for emotional contagion scores. Recordings from the corrugator muscle and heart rate were affected by the stimuli but in a way independent of the perspective taken. Thus, certain facial muscles may be responsive only when adopting certain perspectives during empathy for pain.

To better understand the temporal features of the empathy-related responses to pain, ERPs may be used. From this work, pain relevant stimuli seem to become differentiated from neutral stimuli at an early stage (140 ms) over the frontal lobe with a second longer latency (380 ms) component emerging over central-parietal regions, particularly over the left hemisphere (Fan and Han, 2008; Han et al., 2008). The long latency response also tends to be modulated more by task demands in females than in males (Han et al., 2008). The two ERP components may reflect an early automatic emotion contagion of the pain felt and followed by a controlled cognitive evaluation of the pain stimulus (Fan and Han, 2008). Mu, Mao, and Han (2008) used wavelet analysis of EEG and found that pain-related stimuli increased theta event-related synchronization at 200 to 500 ms and decreased alpha event-related desynchronisation at 200 to 400 ms. The theta band event-related synchronization and alpha band event-related synchronization were positively and negatively correlated with subjective ratings of perceived pain, respectively. The involvement of theta and alpha oscillations suggests that emotion sharing and emotion regulation are implicated in empathy for pain.

Correlations with Self-Reports of Empathy

Perhaps the most straightforward evidence that psychophysiological measures can provide a valid means to examine empathy is that they correlate with self-report measures of the construct. Research investigating this convergence may also illustrate the relative advantages and disadvantages of the two approaches to studying empathy. Self-report measures can be more specific than psychophysiological measures. As such, self-reports may be better able to distinguish between the different components of empathy. However, they may be prone to self-presentation bias and a lack of self-awareness in some people.

Psychophysiological responses, while being more objective, can be elicited by a range of different stimuli and thus have their own interpretational challenges when trying to relate them to specific components of empathy.

Neuroimaging studies have yielded significant correlations between brain regions activated by empathy-related tasks and self-report measures. Using fMRI, changes in the somatosensory cortex, inferior frontal gyrus, superior temporal sulcus, and middle temporal gyrus were positively correlated with self-reported cognitive empathy as measured by the Perspective Taking and Fantasy subscales of the Interpersonal Reactivity Index (Hooker et al., 2010). Activity in the precentral gyrus was also positively correlated with self-reported affective empathy as measured by the Empathic Concern and Personal Distress subscales of the Interpersonal Reactivity Index. Additionally, activity in the anterior insular has been significantly positively correlated with empathy scores as measured by the Impulsiveness-Venturesomeness-Empathy Questionnaire (Eysenck and Eysenck, 1991) in conduct disordered adolescents (Sterzer, Stadler, Poustka, and Kleinschmidt, 2007). Activation in the anterior insula and adjacent frontal operculum when viewing pleased and disgusted facial expressions in others is correlated with empathy scores from the Interpersonal Reactivity Index (Jabbi et al., 2007). Using PET, empathy scores were positively correlated with metabolism in the medial aspects of the superior frontal gyrus (Shamay-Tsoory et al., 2005). Using EEG during a pleasurable task in 6 to 10 year old children, self-report measures of empathic concern and positive empathy were related to increased right frontopolar activation. A second form of positive empathy was related to increasing left dorsolateral activation (Light et al., 2009) thus highlighting the role of prefrontal activity in association with empathy.

Subjective empathy scores are also correlated with facial EMG when viewing images. Westbury and Neumann (2008) found that corrugator EMG paralleled self-report empathy ratings made to human and non-human animal stimuli depicted in negative circumstances. Moreover, corrugator EMG was positively related to trait empathy scores on the Balanced Emotional Empathy Scale (Mehrabian, 1996). This difference was present for bird, quadruped mammal, and human stimuli but was absent for primate stimuli. The lack of an effect for the primate stimulus was attributed to the lower clarity in the images used, thus interfering with the corrugator EMG activity when viewing.

Facial EMG during pictures of happy and angry facial expressions has also been shown to be related to trait empathy as measured by the Questionnaire Measure of Emotional Empathy (Mehrabian and Epstein, 1972; Sonnby-Borgström, 2002; Sonnby-Borgström, Jönsson, and Svensson, 2003). Moreover, the relationship may be influenced by stimulus exposure times. When stimuli were presented at short exposure times (17-40 ms) that are thought to promote automatic reactions, high empathy participants showed stronger facial EMG indicative of mimicry than low empathy participants (Sonnby-Borgström, 2002). In particular, low empathy participants showed zygomatic muscle activity during an angry face, which is contrary to expectations given the relationship between zygomatic activity and smiling. The high empathy participants showed higher corrugator activity during angry faces. It is noteworthy that these EMG differences between empathy groups were present even though there were no differences in self-reported feelings to the faces. Thus, the effects of trait empathy may be more pronounced during initial and automatic reactions to empathy-eliciting stimuli and less so when conscious processing and evaluation of the stimulus can occur.

Special Populations

The social relevance of empathy means it is a construct that is important for several special populations. Some psychological disorders, such as antisocial personality disorder and conduct disorder, are thought to have empathy deficits as a core component (e.g., Söderström, 2003). Empathy deficits may be more peripheral in other disorders (e.g., schizophrenia), but can also be implicated. A unique perspective into empathy may be gained by looking at how psychophysiological measures of empathy are different in special populations and how they might change over the course of treatment.

Antisocial personality disorder (often simply termed psychopathy) describes individuals that are self-centered, seek power over others, are callous, experience little remorse, and can act aggressively towards others (American Psychiatric Association, 1994). It has been argued that psychopathy is a disorder of empathy (e.g., Söderström, 2003). Psychopaths show little regard for others' needs and feelings unless they coincide with their own or suit their purposes. Due to the link with empathy, it may be hypothesized that psychopaths will not show the expected pattern of startle modulation to pictures that differ in valence. Research has generally been consistent with this hypothesis (see Patrick, 1994 for a review).

For example, Patrick et al. (1993) found the normal pattern of smaller startle responses when psychopaths viewed pleasant pictures compared to neutral pictures. When the psychopaths viewed unpleasant pictures, however, startle responses were smaller than during neutral pictures (see also, Pastor, Molto, Vila, and Lang, 2003). The expected pattern of larger startle responses during unpleasant pictures was found in a non-psychopath control group and a mixed group of individuals that were above the cutoff for non-psychopaths but below the cutoff for psychopathy. Interestingly, the differences between the groups were limited to startle responses because the psychopathys, non-psychopaths, and mixed groups showed a similar pattern in skin conductance and heart rate deceleration to the pictures. The abnormal startle modulation during unpleasant stimuli in psychopaths points to an abnormality in processing negative stimuli and may extend to deficiencies in processing negative social situations when others are in need. Supporting this conclusion are correlational analyses that indicated an inverse relationship between emotional detachment and startle modulation during the unpleasant pictures (Patrick et al., 1993).

However, other research has found more extensive deficits in affective responses in the psychopathic population. Herpertz et al. (2001) presented psychopaths with positive, neutral, and unpleasant images. A large proportion of psychopaths did not show any reliable startle blinks (9 of the 25 tested). In those that did respond, there were no differences across the image valence categories, although a difference did emerge in control participants. The psychopaths also had reduced skin conductance responses to the images compared to controls, although they were still larger during pleasant and unpleasant images than during neutral images. Corrugator EMG was not significantly different between the slide valence categories in the psychopaths and overall activity was lower in the psychopaths than in the controls. The pattern of results thus supports the results of earlier studies with unpleasant stimuli and suggests a deficit in anxiety and fear in psychopaths (Patrick, 1994). Furthermore, at least in some situations, psychopaths may have a general abnormality in processing all types of affective stimuli. This latter effect increases the relevance of empathy deficits in psychopathy given that empathy is a state that can be evoked when targets are observed in either negative or positive emotional circumstances (Jabbi et al., 2007).

Conduct disorder shares some characteristics with antisocial personality disorder and is of two main types: childhood onset and adolescent onset. Children or adolescents with conduct disorder can be aggressive to others, destroy property, be deceitful, and violate rules set by society or their caregivers (American Psychiatric Association, 1994). Adolescents diagnosed with conduct disorder have scored lower on empathy as measured by the Impulsiveness-Venturesomeness-Empathy Questionnaire (Eysenck and Eysenck, 1991) and have reduced grey matter volume in the bilateral anterior insular cortex and medial part of the left amygdala when compared to matched controls (Sterzer, Stadler, Poustka, and Kleinschmidt, 2007). Moreover, the bilateral anterior insular grey matter volume in the conduct disorder adolescents was significantly positively correlated with empathy scores (Sterzer et al., 2007).

Facial EMG in the zygomaticus major and corrugator supercilli muscles have also been examined in 8-12 year old boys with either conduct disorder or oppositional defiant disorder (Wied et al., 2006). Dispositional emotional empathy scores and corrugator EMG responses in reponse to angry expressions were smaller in these boys compared to a matched control group. The groups did not differ in zygomaticus EMG activity or heart rate deceleration. The smaller responses to angry expressions in the behaviourally disordered group may signify a deficient early component in the processing of angry expressions and other negative stimuli and thus play a role in impaired empathic responding in these disorders.

Conduct disordered adolescents appear to show a complex pattern of brain abnormalities in empathy for pain. When these adolescents viewed pictures of people in pain caused by accidents, there was increased activity in the anterior midcingulate cortex, striatum, and left amygdala relative to controls (Decety et al., 2009). When these adolescents viewed pictures of people in which pain was caused intentionally, there was reduced activity in neural regions that contribute to self regulation and metacognition, such as the dorsolateral pre-frontal cortex, posterior cingulate cortex, temporoparietal junction, dorsal and medial ACC, and lateral orbitofrontal cortex. In addition, activation of the left dorsolateral pre-frontal cortex and right superior frontal gyrus was greater in controls than in conduct disordered subjects. The greater activity in the pain matrix when viewing accidentally caused pain is contrary to other fMRI findings of reduced amygdala response in conduct disordered adolescents when viewing unpleasant pictures (Marsh et al., 2008; Sterzer et al., 2005) and the reduced overall amygdala volume (Sterzer et al., 2007).

Though not as prominent as with conduct disorder or antisocial personality disorder, other psychiatric disorders may involve a component of diminished empathy-related responding. Empathy deficits have been implicated in social dysfunction in schizophrenia, post traumatic stress disorder, and dysphoria. Using a somewhat complex cartoon empathy task, patients with schizophrenia have showed less activation in the right temporal lobe during an emotional empathy task, greater activation in the left insula in a cognitive empathy task, and greater activation in the right middle cortex and inferior frontal cortex than in matched controls (Lee et al., 2010). Activation in regions of the brain implicated in empathy and social reasoning judgements (left anterior and posterior middle temporal gyrus, and posterior cingulate gyrus/precuneus) have changed over the course of therapy in post traumatic stress disorder patients (Farrow et al., 2005). Dysphoric persons have shown a lack of an increase in zygomatic EMG activity and an increase in corrugator EMG activity in response to happy facial expressions (Sloan et al., 2002). Children with austistic spectrum disorder showed lower fusiform gyrus activation when viewing emotional faces and reduced congruent

reactions and inferior frontal gyrus activity when inferring their own emotional responses to the faces (Greimel et al., 2010). While the spectrum of disorders is varied and further research is required to show that the effects are specifically related to the construct of empathy, the findings indicate that psychophysiological investigations of empathy can give useful insights into the recognition, experience, and demands in interpreting the social signals of emotion in a range of psychological disorders.

Researchers have also used psychophysiological methods to study empathy-related responses in non-psychiatric special populations for which empathy may be an important component. Decety et al. (2010) found differentiation in early N110 and late P300 over the central-parietal regions to images of body parts being pricked with a needle versus a Q-tip (cottonbud) in control participants, but not in physicians. The authors argued that the physicians have a down-regulation of empathy pain reactions due to their repeated exposure to suffering of others in healthcare and that this dampening of arousal helps them to function better in medical contexts. In a psychotherapy context, skin conductance and heart rate measures have showed strong concordance between a client and therapist during the sessions (Marci and Riess, 2005). However, the client also exhibited increases in arousal that had not been noticed by the therapist. An examination of the increases in the physiological data improved the empathic awareness in the therapist and facilitated the therapeutic relationship between the two individuals.

FURTHER RESEARCH DIRECTIONS ON THE PSYCHOPHYSIOLOGICAL MEASUREMENT OF EMPATHY

In any developing field, there is potential for many research questions to be answered in further work. Further research is required to examine the interrelationships between the various psychophysiological measures. Each has shown advantages and disadvantages in the ways they examine the complex construct of empathy. Neuroimaging provides an effective means to localize the brain structures that are involved in empathy; however this data need not be limited to anatomical descriptions. For example, when tasks are varied and outcomes are cross-referenced with other research, the contribution these activations make to empathy as a psychological entity can be more accurately inferred. EEG and ERPs have superior temporal resolution than is possible with neuroimaging and are particularly well suited to study automatic processes. Facial EMG provides indicators of mimicry and understanding of emotional expressions. Further empathy research could apply EMG measures to examine mimicry more extensively. For example, research can look at mimicry of the full range of facial expressions (e.g., disgust, anger) and examine other aspects of mimicry (e.g., postural mimicry, general tonic arousal). Heart rate and skin conductance responses provide good indicators of autonomic activity and can be related to a wealth of research already conducted on these measures in the areas of attention and emotion. The concurrent recording of the skin-conductance response with brain activation has been initiated (e.g., Decety and Chaminade, 2003) and such applications may add to our understanding of empathy.

Empathy is a multidimensional construct and comprises the ability to perceive, understand and feel the emotional states of others. However, most studies have tended to rely on studying a single aspect of empathy, such as perspective taking or emotion perception.

Further research could use more diverse tasks within a single experimental session to ensure that the various components of empathy are studied. For example, Derntl et al. (2010) developed three paradigms to assess three core components of empathy (emotion recognition, perspective taking, and affective responsiveness) in an fMRI study. Westbury and Neumann (2008) have also changed the type of targets in empathy-eliciting scenes to extend the study of empathy towards non-human animals.

Empathy is not a construct that is present to the same degree in all people. The observation of differences in empathy in special populations, as noted above, shows that this is the case. Future research may also examine individual differences more extensively in the normal population. For example, Gale et al. (2001) asked female participants to empathise with male and female photographs that showed positive or negative emotions. Recordings from the EEG showed that positive and negative facial expressions produced different activity at frontal leads and temporal leads and between the hemispheres (e.g., greater frontal activity in the left hemisphere with negative expressions). However, impacting upon this pattern of results was the effect of participant personality. Participants that were more extraverted showed widespread enhanced alpha amplitude and those that were more neurotic showed greater inter-hemispheral differences in activity. Sex differences may also emerge as another important individual difference variable. Derntl et al. (2010) used fMRI to show that empathy-related processing may activate somewhat different neural networks in males and females. Females showed stronger overall neural activation in areas that regulate processing of emotion, including the amygdala. In contrast, males seem to use more cognitive-related processing regions. These effects suggest that neglecting to consider individual differences in empathy research will inflate the error term (Gale et al., 2001) and potentially obscure the richness of empathy findings across the general population.

Further research may also examine constructs that share some overlap with empathy to determine what is both similar and unique about them. Empathy, sympathy, and distress are highly correlated (Westbury and Neumann, 2008) and further research is required to determine in which brain regions these functions overlap, and to what extent they elicit mimicry and mirror neuron activity (see e.g., Decety, 2011). For example, Farrow et al. (2001) asked participants to make judgments of empathy and forgivability for various scenarios. Both types of judgments produced neural activity in the left anterior middle temporal and left inferior frontal gyri. In contrast, forgivability judgments activated the posterior cingulated gyrus. These findings suggest that while there are some similarities, there are also important differences between empathy and forgivability in what brain regions they activate. There can be a complex interplay between different responses in social interactions and circumstances. Stimuli used in empathy research investigating this interplay can elicit a range of responses that both do and do not implicate the core components of empathy. This research has the potential to shed light on what physiological responses are unique to empathy and what are shared with related constructs.

CONCLUSION

The psychophysiological measurement of empathy is a rapidly developing field within empathy research. Improvements in technology for well-established psychophysiological

measures, the explosion in the use of neuroimaging techniques, and the emergence of the 'social neuroscience' of empathy (Decety, 2007; Decety and Ickes, 2009) are all factors that have contributed to this trend. Perhaps of greater significance has been a shift in emphasis for researchers to map the biological basis of empathy and explore the ideas of emotional contagion, mirror neurons, mimicry, and how empathy is different in special populations. While future research that uses a psychophysiological approach will make significant contributions to our understanding of empathy, it is unlikely that it will be able to tell us the whole story. For such a complex and multifaceted construct as empathy, it is necessary for researchers to use diverse research approaches and measures to gain a complete understanding. Non-psychophysiological approaches that have relied on self-report and behavioural measures have already given many insights about empathy. If this knowledge gained can be furthered by the use of psychophysiological measures, there is the potential that we can finally answer some of the fundamental questions about what empathy is, how it influences our behavior, and what we can do to promote the development of empathy and prosocial behaviour in society.

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