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A Behavioural and Electrophysiological Exploration into Facial and Vocal Emotion Processing in Children with Behaviour problems

by

Georgia Chronaki

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<u>ABSTRACT</u>

FACULTY OF LAW, ARTS & SOCIAL SCIENCES

SCHOOL OF PSYCHOLOGY

<u>Doctor of Philosophy</u>

A BEHAVIOURAL AND ELECTROPHYSIOLOGICAL EXPLORATION INTO FACIAL AND VOCAL EMOTION PROCESSING IN CHILDREN WITH BEHAVIOUR PROBLEMS

by Georgia Chronaki

The present thesis consists of two parts: a behavioural and an electrophysiological exploration of children's facial and vocal emotion processing. Former research has suggested that social dysfunctioning in school-aged children with behaviour problems may stem from difficulties in understanding others' emotions from facial expressions. Study 1 examined emotion processing difficulties, from facial and vocal expressions, in preschool children with externalising and internalising behaviour problems from the community. Study 1 provided evidence for vocal emotion processing difficulties in preschoolers with externalising but not internalising symptoms. Studies 2 and 3 examined the development of facial and vocal emotion processing and investigated emotion processing difficulties in school-aged children with externalising and internalising symptoms. Study 4 addressed the cognitive processes (ERPs) underlying vocal anger processing in children and isolated a neural marker of vocal anger processing. This emotion modulation of children's brain potential was not observed during facial anger processing (Study 5). Study 4 provided initial evidence for links between a neural marker of vocal anger processing and emotion dysregulation and conduct problems. In contrast, non emotion-specific difficulties in face processing were associated with internalising symptoms (anxiety and depression) in children. The present research highlights the potentially salient role of vocal anger processing in child externalising psychopathology.

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Ithaca

As you set out for Ithaca
hope your road is a long one,
full of adventure, full of discovery.
Laistrygonians, Cyclops,
angry Poseidon - don't be afraid of them:
you' ll never find things like that on your way
as long as you keep your thoughts raised high,
as long as a rare excitement
stirs your spirit and your body.
Laistrygonians, Cyclops,
wild Poseidon - you won't encounter them
unless you bring them along inside your soul,
unless your soul sets them up in front of you.

Hope your road is a long one.
May there be many summer mornings when,
with what pleasure, what joy,
you enter harbours you're seeing for the first time;
may you stop at Phoenician trading stations
to buy fine things,
mother of pearl and coral, amber and ebony,
sensual perfume of every kind -
as many sensual perfumes as you can;
and may you visit many Egyptian cities
to learn and go on learning from their scholars.

Keep Ithaca always in your mind.
Arriving there is what you're destined for.
But don't hurry the journey at all.
Better if it lasts for years,
so you're old by the time you reach the island,
wealthy with all you've gained on the way,
not expecting Ithaca to make you rich.

Ithaca gave you the marvelous journey.
Without her you wouldn't have set out.
She has nothing left to give you now.
And if you find her poor, Ithaca won't have fooled you.
Wise as you will have become, so full of experience,
you'll have understood by then what these Ithacas mean

Konstantinos Kavafis

DECLARATION OF AUTHORSHIP

I, ………………………………………………………………………., [please print name]

declare that the thesis entitled:

'A Behavioural and Electrophysiological Exploration into Facial and Vocal Emotion Processing in Children with Behaviour Problems'

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
- none of this work has been published before submission.

Signed: ………………………………………………………………………..

Date:………………………………………………………………………..

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ADHD	Attention Deficit Hyperactivity Disorder
ADHD-CBS	Attention Deficit Hyperactivity Disorder-Current Behaviour Scale
ANOVA	Analysis Of Variance
APA	American Psychiatric Association
BESA	Brain Electrical Source Analysis
Br	Bias Response
CBQ	Child Behaviour Questionnaire
CD	Conduct Disorder
DANVA	Diagnostic Analysis of Non-verbal Accuracy
dB	Decibel
EEG	Electroencephalogram
EPN	Early Posterior Negativity
ERC	Emotion Regulation Checklist
ERP	Event-Related Potential
ESL	Early Slow Wave
vEOG	Vertical Electro-Oculogram
F0	Fundamental Frequency
fMRI	Functional Magnetic Resonance Imaging
FTPV	Fronto Temporal Positivity to Voice
GHQ	General Health Questionnaire
2HT	Two High Threshold
ICA	Independent Component Analysis
ITI	Inter-Trial Interval
IQ	Intelligence Quotient
LPP	Late Positive Potential
LSW	Late Slow Wave
MEG	Magnetoencephalography
MMN	Mismatch Negativity
MRI	Magnetic Resonance Imaging
NHS	National Health Service
NIRS	Near-Infrared Spectroscopy
ODD	Oppositional Defiant Disorder
Pa	Pascal
PET	Positron Emission Tomography
PCA	Principal Component Analysis
PSOC	Parenting Sense of Competence
SDQ	Strengths and Difficulties Questionnaire

SPL	Sound Pressure Level
STS	Superior Temporal Sulcus
SW	Slow Wave
VSR	Voice Specific Response
WWP	Werry Weiss Peters Activity Scales

Thesis Overview

Emotion cannot be defined as a unitary concept: it has as many definitions as the theoretical and conceptual approaches proposed to describe it (Strongman, 2003). Emotion is an organized set of responses with physiological, behavioural, cognitive and subjective feeling components, which serves motivational and adaptive functions (Izard, Woodburn, & Finlon, 2010). Six basic emotions, namely, anger, happiness, sadness, fear, disgust and surprise have been proposed according to descriptions of distinct facial muscle movements (Ekman & Friesen, 1971).

The present thesis opens with a brief discussion of the relationship between emotion processing from facial and vocal cues and social competence in children. Chapter 1 provides a review of the developmental literature in the recognition of the six basic emotions from facial expressions. Subsequently, Chapter 1 reviews the development of children's recognition of vocal expressions of basic emotions and highlights the importance of incorporating vocal as well as facial expressions in the study of emotion recognition.

The present thesis aims to extend knowledge bridging emotion processing and child psychopathology, with a particular focus on externalising psychopathology. Chapter 2 opens with an overview of the most common behaviour problems of childhood, including hyperactivity, conduct problems and anxiety. The social dysfunctioning in children with behaviour problems and its impact on children's friendships is discussed. Theoretical models of emotion processing in children with behaviour problems are presented, with a focus on externalising psychopathology. These models can be summarised in the debate between general inattention versus specific emotion processing difficulties. Chapter 2 briefly reviews recent evidence proposing that inaccurate understanding of other's emotions may contribute to social skills difficulties in children with behaviour problems. Chapter 2 examines the evidence supporting facial and vocal emotion processing deficits and biases in children with hyperactivity, conduct problems and anxiety. Finally, the role of parent characteristics, such as parental psychopathology and parenting-self-esteem in children's emotion processing is discussed.

The first empirical chapter of the thesis (Chapter 3) provided an exploration into facial and vocal emotion processing in preschoolers with externalising and internalising behaviour problems. Potential difficulties in this developmental period have not been investigated in previous research. Chapter 3 provides some preliminary evidence that emotion processing difficulties *do* exist in preschoolers with behaviour problems and that these difficulties are limited to vocal but not facial expressions across all emotions in pre-school children with hyperactivity and conduct problems. The chapter also provides limited support to the relationship between parent characteristics and children's emotion processing.

The second empirical chapter of the thesis (Chapter 4) aims to further develop a more appropriate battery of vocal emotional stimuli. A new set of vocal stimuli was developed which measures perception of emotion from vocal expressions devoid of language content, in order to disentangle emotion processing from language processing. Chapter 4 validated the new vocal stimuli in a small sample of 5- to 7-year-old children and adults from the community. After a pilot validation study of emotional prosody stimuli, Chapter 4 studied the development of facial and vocal emotion processing in a larger sample of 4- to 10-year-old children and adults from the community. Chapter 4 revealed developmental patterns in facial and vocal emotion processing. In parallel, associations between emotion recognition and psychopathology in children and adults were explored.

Following a behavioural exploration into facial and vocal emotion processing in children, this programme of research aims to uncover the neural underpinnings, in terms of ERPs, of emotion processing in children with behaviour problems. Prior to the presentation of the ERP studies, a brief introduction to Event-Related-Potentials (ERPs) is provided. Chapter 5 discusses the functional significance of the most frequently studied ERP components in the face and voice processing literature. Chapter 5 reviews existing knowledge on the neural underpinnings of facial and vocal emotion recognition in children. Chapter 5 presented a brief review of existing knowledge in the neural markers of non-emotional and emotional information processing in children with hyperactivity, anxiety and conduct problems. Finally, the role of parent characteristics on children's neural development of emotion processing is discussed.

The ERP studies conducted in the context of the present thesis adopted a special focus on anger processing. Study 4 examines the electrophysiological correlates of vocal anger processing. Study 5 examines the electrophysiological correlates of facial anger processing. As both studies (Study 4 and Study 5) were based on the same sample of participants, Chapter 6 describes the general ERP methods adopted for the two studies.

Study 4 (Chapter 7) identified a neural marker of vocal anger processing, consisting of the temporoparietal and occipital N400 component, in a large sample of typically developing children from the community. In addition, Chapter 7 aimed to extend previous knowledge by exploring the relationship between a neural marker of vocal anger processing and child externalising and internalising behaviour problems. Finally, Chapter 7 explored the role of parent characteristics, such as parental psychopathology and parenting self-esteem, in children's vocal anger processing.

Study 5 (Chapter 8) aimed to clarify whether the neural marker of anger processing identified in Chapter 7, extended also to facial expressions or was specific to vocal expressions. In the same sample as in the previous study, Chapter 8 explored the electrophysiological correlates of facial anger processing. Chapter 8 found that brain activity patterns (ERPs) were not affected by the emotional significance (anger) of the facial expressions, as was the case with vocal expressions. In addition, Chapter 8 revealed a negative relationship between general face processing ability and internalising symptoms, such as anxiety and depression, in children.

The present thesis ends with a brief summary of the findings of the current programme of research (Chapter 9). Chapter 9 opens with a brief overview of the current findings. Subsequently, Chapter 9 discusses the significance of the findings and their contribution to theoretical frameworks. Clinical implications and limitations of the research findings are briefly discussed and directions for future research are suggested.

Chapter 1. The Development of Emotion Processing

1.1 Chapter Overview

Facial emotional expressions carry a wealth of information and play a cardinal role in daily social communication (Ekman, 1994). The process of recognising facial expressions of emotion consists of that of perception (i.e. the ability to discriminate features of an expression) and that of recognition of meaning (Adolphs, 2002). Recognition of meaning refers to linking perceptual information to some form of conceptual information about the meaning conveyed by the expression or knowledge of the verbal label for the expression (Adolphs, 2002). Developmental theories highlight that recognising facial expressions of emotion is a process involving both perceptual (i.e. visual discrimination) skills, (Gosselin & Simard, 1999) and conceptual abilities such as understanding of the meaning of emotion categories (Widen & Russell, 2008).

Emotion recognition has early developmental origins. Infants can recognise facial and vocal expressions (i.e. social referencing) before they can produce verbal labels (Klinnert, Campos, Sorce, Emde, & Svejda, 1983; Vaish & Striano, 2004). Use of emotion words emerges towards the end of the second year of life (Bretherton, Fritz, Zahn-Waxler, & Ridgeway, 1986), based on others' behavioural cues (Smiley & Huttenlocher, 1989) and is facilitated by emotional dialogue with family members (Dunn, 1996; Dunn & Brown, 1994). Three-year-olds understand that others have wishes, beliefs and feelings (Harris, 1989) and can label the emotions of others (Saarni, 1999). Although two-year-olds can understand verbal labels for facial emotional expressions (Michalson & Lewis, 1985), it is only between 2 and 4 years of age children begin to acquire situation-based knowledge, such as understanding of the situations that elicit different emotional reactions (Barden, Zelko, Duncan, & Masters, 1980; Wellman, Harris, Banerjee, & Sinclair, 1995). Preschoolers are better at recognising verbal labels compared to facial expressions (Camras & Allison, 1985). Four and five-year-olds can accurately recognise happy, sad and angry facial expressions (Bullock & Russell, 1984). Recognition of self-conscious emotions (e.g. embarassment) continues to develops throughout the school years (Saarni, 1999).

The present chapter will open with a discussion on the relationship between emotion processing and social competence and will subsequently review the development of recognition and labelling of facial and vocal emotional expressions during childhood.

1.2 Emotion Processing and Social Competence

Individual differences in emotion processing are closely related to children's social adjustment (Mostow, Izard, Fine, & Trentacosta, 2002; Philippot & Feldman, 1990). A recent meta-analytic review of 63 independent samples, detected an effect size of .22 of relations between 'emotion knowledge', including, among others, recognition tasks of facial and vocal emotional expressions and internalising and externalising problems (Trentacosta & Fine, 2010). Children who were better able to understand non-verbal emotional cues in social interactions developed better social skills and formed positive interpersonal relationships over time (Denham, 1998; Saarni, 1999).

Developmental research has demonstrated links between pro-social behaviour and accuracy to recognise others' emotions, including recognition of angry, happy and sad facial expressions (Ensor & Hughes, 2005). Emotional competence at 3 and 4 years contributed to social competence not only concurrently but also across time, suggesting that emotional competence during the preschool years can have a long-term effect on children's social competence (Denham et al., 2003). The ability to recognise basic emotions from facial expressions was related to peer-popularity and teacher-rated social competence in 7- to 10-year-olds (Leppänen & Hietanen, 2001).

Research has consistently linked sensitivity to vocal emotional expressions and social adjustment (Goodfellow & Nowicki, 2009). In adults, the ability to decode vocal expressions affected the quality of close relationships (Koerner & Fitzpatrick, 2002), emotion regulation skills (Siegman & Boyle, 1993) and enhanced satisfaction with social interactions (Roberts & Nowicki, 1999). In relation to development, sensitivity to vocal emotion has been linked to socio-metric status in preschoolers (Nowicki & Mitchell, 1998), teacher ratings of children's peer relationships (Maxim & Nowicki, 1997) and more symbolic play with parents (Bornstein, 2000). Research with school-aged children has demonstrated links between low sensitivity to vocal emotional expressions and teacher ratings of depression and hyperactivity (Rodemaker, 1999). In adolescence, low sensitivity to vocal emotion has been associated with personality disorders (Mitchell, 1995) and a higher risk for dropping out of school (Sisney, Strickler, Tyler, Duke, & Nowicki, 2001).

The above findings converge to the conclusion that the ability to understand emotions from non-verbal cues plays a fundamental role in children's social adjustment.

1.3 The Development of Facial Emotion Processing

Facial emotion processing has its origins in infancy (Brazelton, Koslowski, & Main, 1974; Muir, Lee, Hains, & Hains, 2005; Trevarthen & Aitken, 2001). From the first days of life infants preferentially attend to face-like patterns (Morton & Johnson, 1991). At three months, infants can recognise individual facial expressions (de Haan, Johnson, Maurer, & Perrett, 2001) and at approximately six months, infants can discriminate between different facial emotional expressions (Kobiella, Grossmann, Reid, & Striano, 2008; Leppänen & Nelson, 2006; Nelson & de Haan, 1997) and respond differentially to discrete emotional expressions (Kahana-Kalman & Walker-Andrews, 2001). By the first year of life, infants have established the ability not only to recognise emotion from facial expressions, but also to adjust their social behaviour to the emotional message conveyed by such expression (Hertenstein & Campos, 2004). Despite its early developmental origins, facial emotion processing continues to develop from the preschool years through to middle childhood and adolescence (Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007; Herba & Phillips, 2004; Wade, Lawrence, Mandy, & Skuse, 2006).

Developmental research suggests a continuing improvement of facial emotion recognition accuracy with age. Children at five years of age were more accurate at matching emotion photographs to vignettes compared to three-year-olds (Boyatzis, Chazan, & Ting, 1993; MacDonald, Kirkpatrick, & Sullivan, 1996a, 1996b). Similarly, children between the age of 3 and 7 increased systematically the number of labels they gave to facial expressions in free labelling tasks (Widen & Russell, 2008). The ability to match facial emotional expressions to short stories improved significantly from 5 to 8 years (Gosselin, Roberge, & Lavallée, 1995). A significant improvement of facial expression recognition and reading emotion from eyes has been found to occur at 11 years of age in a sample of 9- to 15-year-olds, suggesting that pre-adolescence marks an important developmental stage for the recognition of facial emotion (Tonks, Williams, Frampton, Yates, & Slater, 2007). Despite recognition of basic emotions, such as anger, happiness and sadness, being well established by six years of age, recognition of more complex social emotions, such as shame, continues to develop gradually throughout childhood (Markham & Adams, 1992).

Research has shown that 9- to 12-year-old children recognised happiness and sadness at higher accuracy rates followed by anger, fear and disgust (Vicari, Reilly, Pasqualetti, Vizzotto, & Caltagirone, 2000). However, other studies have found that 4- to 18-year-olds recognised happiness with higher accuracy compared to fear, disgust, sadness and anger (Montirosso, Peverelli, Frigerio, Crespi, & Borgatti, 2010). In addition, the developmental trajectory of recognition accuracy can be dependent on the type of emotion. For example, the ability to match the emotion of a target face with one of two choices improved from 4 to 15 years of age for fear, disgust, happiness, sadness but not anger (Herba, Landau, Russell, Ecker, & Phillips, 2006). Other studies have shown that younger children (i.e. 5-6 and 7-8 years) were less accurate than adults to match emotion labels to sentences describing an emotional state for anger, but there were no significant differences between young children and adults in the above task for happiness and sadness (Durand et al., 2007). Finally, one study has found that developmental trajectories in facial emotion recognition and labelling tasks were particularly pronounced for emotions such as disgust, surprise and fear (Vicari et al., 2000). Research has shown that seven-year-old children could accurately recognise fearful expressions and twelve-year-old children could recognise disgust from facial expressions (Durand et al., 2007). In summary, despite the relatively well-established developmental effects on facial emotion recognition accuracy, the developmental pattern of recognition accuracy is not uniform across emotions.

The preschool years constitute a landmark in the development of emotion understanding (Denham et al., 2003; Wellman, Cross, & Watson, 2001). Free labelling tasks have shown that preschoolers at two and a half years produced no emotional labels to photographs of facial expressions whereas preschoolers at three and three and a half years produced the labels 'happy', 'angry' and 'sad'. In the same study preschoolers at four years added the label 'scared' or 'surprised' to their emotion vocabulary (Widen & Russell, 2003). Consistent with these findings, happiness and sadness were the first emotions to be recognised during the preschool years and with highest accuracy rates (Camras & Allison, 1985; Gosselin, 2005; Vicari et al., 2000). At four and five years of age children were able to accurately recognise happy, sad and angry facial expressions (Bullock & Russell, 1984; Gosselin, 2005; Wade et al., 2006). Preschoolers showed low recognition accuracy for fearful facial photographs (Boyatzis et al., 1993; Camras & Allison, 1985) and they also had difficulty recognising disgust, which they tended to associate with anger (Gagnon, Gosselin, Hudon-ven der Buhs, Larocque, & Milliard, 2010; Widen & Russell, 2008).

The developmental pattern of emotion recognition during the preschool years is also dependent on different methodologies - whether preschoolers are asked to recognise (match) an emotional expression to a given label, or are given an expression and asked to provide a label for it. For example, children as young as two and a half years of age could discriminate between basic expressions of emotion, but the ability to label these emotions developed later in life (review by Gross & Ballif, 1991; Izard, 1971). Recent research has shown that before using 'fear' in free labelling tasks, preschoolers were able to include ‘fear’ faces in a box where i.e. ‘only the fear people go’ in categorisation tasks and the same pattern emerged for happiness, anger and sadness (Widen & Russell, 2008). These findings suggest that preschoolers can recognise and discriminate facial expressions before they can give them a verbal label. Developmental research has also shown that three to four-year-old children presented higher accuracy to recognise emotions and describe causes of emotions such as happiness, anger, fear, disgust and surprise when these emotions were introduced to the children through a verbal label (word) by the experimenter (i.e. do you sometimes feel angry?) than through a visual channel such as facial photographs (i.e. do you sometimes feel this way?) (Russell & Widen, 2002). Research with preschoolers has shown high correlations between accuracy for facial photographs and face drawings (MacDonald et al., 1996b).

Facial emotion recognition accuracy rates in school-aged children can also vary as a function of methodologies used to assess accuracy in this age group (De Sonneville et al., 2002). Recent evidence suggests that different tasks such as matching tasks for emotional faces compared to emotion labelling tasks recruited different types of cognitive capacities in school-aged children (i.e. visual-spatial compared to lexical-semantic respectively) and as a result produced different accuracy rates for different emotions (Vicari et al., 2000). Other studies have found corresponding developmental patterns in emotion understanding, for different tasks, such as emotion labelling and drawing tasks (Brechet, Baldy, & Picard, 2009). Similar research has shown that recognition accuracy was poorer at free labelling tasks compared to forced choice labelling tasks, although the ordering of emotions from easiest to most difficult to recognise in 4, 6 and 8-year-olds was constant across tasks (Markham & Adams, 1992).

Developmental research in adolescence is more limited. Adolescents have been found to be more accurate at recognising facial emotional expressions than children (Montirosso et al., 2010; Nowicki & Duke, 1994). Research with 9- to 15-year-olds indicates that children under eleven made significantly more errors in facial emotion recognition in comparison to children aged twelve years or over (Tonks et al., 2007). Facial emotion recognition accuracy continues to develop from late childhood through to adulthood with accuracy to recognise anger in particular showing a steep developmental increase from adolescence to adulthood. In the same study there was a trend for a gradual developmental increase in fear recognition accuracy from childhood through adolescence to adulthood (Thomas, De Bellis, Graham, & LaBar, 2007). Facial emotion processing continues to develop in adulthood with some decline amongst middle-age women in recognising sadness, surprise and fear (Wade et al., 2006) and a general decline in accuracy in older adults (review by Ruffman, Henry, Livingstone, & Phillips, 2008).

Regarding the role of gender, there is currently inconclusive evidence in emotion recognition accuracy. For example, some studies report differences in facial emotion recognition accuracy in favour of girls (Barth & Bastiani, 1997; Montirosso et al., 2010; Wade et al., 2006). A meta-analytic review of studies published between 1970 and 1999 has revealed a small but robust female advantage in processing facial emotion across a range of different methodologies, emotions and intensities (McClure, 2000). In contrast, other studies showed that boys and girls performed at comparable levels of accuracy (De Sonneville et al., 2002; Herba et al., 2006; Thomas, De Bellis, et al., 2007).

In summary, the developmental literature on facial emotion processing has focused on the younger age groups and few studies have looked at the continued development of emotion recognition from childhood into adolescence and adulthood. Developmental research suggests a general improvement in accuracy with age although type of emotion and task can influence the rates of facial emotion recognition accuracy.

1.4 The Role of Intensity in Emotion Processing

Developmental research has focused on the categorical perception of facial emotional expressions and few studies have examined the role of intensity in recognition accuracy. The role of intensity in facial emotion recognition is clearly important for the development of sensitivity to recognise emotional expressions (Hess, Blairy, & Kleck, 1997). As facial expressions in real-life are displayed at different intensities, measurements of intensity levels are more ecologically valid and sensitive in capturing subtleties in emotion processing (Montagne, Kessels, De Haan, & Perrett, 2007).

The study of intensity of emotional expression, therefore, is important for a better understanding of children's emotion recognition patterns. Intensity effects on recognition accuracy are relatively well established in the empirical literature (Herba & Phillips, 2004). Early research has shown that accuracy increased as a function of intensity of the facial expression for happiness and disgust in 9- to10-year-old children (Gosselin & Pelissier, 1996). A recent study investigating the role of intensity in a facial emotion matching task in 4- to 15-year-old children found that accuracy improved (especially for happiness and fear) with higher intensity level (i.e. 50%, 75% and 100%) compared to 25% intensity but not for 75% or 100% compared to 50% intensity. In addition, children were slightly faster to match more intense expressions compared to 25% intensity expressions, particularly for sadness, disgust and happiness (Herba et al., 2006). Similar research has shown that recognition accuracy in 4- to 18-year-old children and adolescents improved for angry, happy, sad, fear and disgust expressions at higher intensity levels (50%, 75% and 100%) compared to 35% intensity expressions (Montirosso et al., 2010). The above findings suggest a critical threshold in intensity for sensitivity to recognise emotion from facial expressions.

It should be noted that intensity effects on accuracy are not uniform across different emotional expressions. For example, research has shown that happy but not angry expressions were more accurately recognised at higher intensity levels (Gosselin et al., 1995). In a similar study, anger and sadness were more difficult to recognise than happiness, fear and disgust when presented at low (i.e. 35%) compared to higher (i.e. 50%, 75% and 100%) intensity levels in tasks using dynamic facial expressions of emotion (Montirosso et al., 2010).

Furthermore, the ability to recognise low intensity facial expressions follows an early and slow developmental course. Past research has shown that infants as young as 7 months were able to discriminate between two happy and two fearful faces varying in intensity (Nelson, 1987). Nonetheless, 5- to 7-year-old children were less accurate than adults in judging which expression was more intense when shown pairs of happy, sad and fearful faces and asked to decide which one looked happier, sadder or more fearful than the other. However, in the same study, 5-year-olds were as accurate as adults at grouping together happy and sad, but not fearful faces of very low intensity (i.e. 20%) (Gao & Maurer, 2009).

Recognition accuracy has been found to improve at low (i.e. 35%) and medium (50%) intensities in older (i.e. 13- to 15-year-old and 16- to 18-year-old) but not in younger (7- to 9-year-old) children. In particular, primary school-aged children were less accurate than adolescents at low (i.e. 35% and 50%) intensity levels across emotions while preschool children did not differ from 7- to 9-year-olds in recognition accuracy for 50% and 75% intensity (Montirosso et al., 2010). In addition, another study that used three emotional blends (neutral to fear, neutral to anger and fear to anger) across six morphing increments varying from 22% to 77% intensity showed that 7-to 13-year-old children and 14- to 18-year-old adolescents were less accurate than adults for both fear and disgust (Thomas, De Bellis, et al., 2007). Recognition accuracy for anger intensity in particular significantly improved from adolescence to adulthood (Thomas, De Bellis, et al., 2007).

In summary, research in the developmental course of processing emotion from faces varying in intensity is important but limited and further evidence is required to elucidate the role of intensity in the development of facial emotion processing.

1.5 The Development of Vocal Emotion Processing

While this body of research has highlighted facial emotional expressions in the development of emotional understanding, further work has suggested that children will utilise other (i.e. vocal) channels of information to facilitate this recognition.

The word '*prosody'* derives from the Greek word '*prosodia'* used to refer to 'song sung with accompaniment' in the fifth century B.C. Emotional prosody refers to changes in the intonation of the voice, according to the speaker's emotional state (Hargrove, 1997). It is well established from the empirical literature and everyday life experience that emotions can be communicated accurately through vocal expressions across cultures (Laukka, 2004), at rates comparable to those reported in studies of facial emotion (review by Juslin & Laukka, 2003). Specific vocal expression patterns for different emotions have been linked to specific acoustic profiles, such as fundamental frequency (perceived as pitch), mean energy (perceived as loudness) and speech rate (Banse & Scherer, 1996). For example, anger is characterised by an increase whilst sadness is defined by a decrease in mean energy (Banse & Scherer, 1996). Adult studies show that vocal and facial emotional signals presented together can convey information above and beyond what can be conveyed by one modality alone (Bachorowski, 1999; Scherer, Banse, Wallbott, & Goldbeck, 1991).

It is noteworthy that the majority of developmental studies in vocal emotion recognition have focused on infancy and there is limited research in the development of vocal emotion recognition in childhood and the preschool years. This is surprising given the prominent role of vocal expressions in children's social interactions. The study of vocal emotion recognition is important for a number of reasons. Vocal emotion processing plays a central role in typical child development. Preschoolers were found to exhibit auditory dominance, processing only auditory information when presented simultaneously with equally discriminable, but unfamiliar, visual and auditory non-emotional stimuli (Sloutsky & Napolitano, 2003). In addition , there was a 'superiority effect' of vocal compared to facial emotional signals in children, especially when the person expressing the emotion was familiar (Shackman & Pollak, 2005). From a developmental perspective, vocal emotions are critical in the context of typical parent-child interactions (Shackman & Pollak, 2005) and can capture attention from a greater distance than facial expressions, as is often the case with caregivers (Fernald, 1993). For instance, infants can perceive the emotional intonation in maternal infant-directed speech, known as 'motherese', a phenomenon observed across cultures and linked to special mother-infant interactions (review by Falk, 2004).

Similar research has highlighted the role of vocal recognition in social referencing and the ability to rely on signals from caregivers in potentially threatening situations. For example, studies using visual cliff paradigms have found that infants crossed the visual cliff faster in the conditions in which mothers provided both vocal and facial or vocal cues only relative to when mothers provided only facial cues (Vaish & Striano, 2004). Studies on infants' learning about novel objects in joint attention conditions with and without vocal cues have found that in the joint attention plus voice condition infants looked significantly longer at the novel objects (Parise, Cleveland, Costabile, & Striano, 2007). These findings underscore the adaptive value of vocal expressions in typical development.

The developmental literature has shown that voice processing has earlier developmental origins than face processing. Studies on foetal voice recognition have found that foetuses could discriminate between their mother's voice and a stranger's voice (Kisilevsky et al., 2003). Similar research has shown that the ability to perceive familiar auditory signals such as maternal voices was in place before birth (DeCasper & Fifer, 1980; Vouloumanos & Werker, 2004). Newborn infants tended to display more eye-opening responses to voice expressing happy emotions rather than angry, sad or neutral emotions (Mastropieri & Turkewitz, 1999). Similar studies have found that infants could regulate their behaviour (i.e. show more negative affect and less toy proximity) in response to fearful vocal signals independently of facial signals (Mumme, Fernald, & Herrera, 1996). Infants also perceived facial and vocal expressions in combination (Walker-Andrews, 1997), for example, by showing a tendency to fixate for longer at faces where the voice matched the emotional expression (Walker-Andrews, 1986).

Despite its early developmental origins, vocal emotion recognition accuracy has been found to improve with development. Research has shown that 3-to 5-year-olds were able to accurately identify and label happy, angry and sad emotions from vocal expressions at accuracy rates comparable to facial channels of presentation (Stifter & Fox, 1986). Further research has shown an improvement with age in preschoolers' ability to recognise the speaker's emotional state from audiotape recordings of situations containing vocal emotional expressions (Hortacsu & Ekinci, 1992). Studies using angry, happy, sad and fearful vocal expressions in emotion recognition tasks have found that 4 and 5-year-old children had error rates of approximately 52% (Mitchell, 1995; Verbeek, 1996) whereas 9 and 10-year-old children made around 37% errors (Maxim & Nowicki, 1997; McClanahan, 1996; Rowe, 1996); suggesting that recognition accuracy improves from the preschool years to middle childhood.

In other studies, accuracy to recognise vocal emotional expressions increased significantly between 4 and 19 years of age, reaching adult-like accuracy rates at about 10 years of age (Baum & Nowicki, 1998). Other studies, however, have not found significant improvement for emotional prosody naming (i.e. labelling vocal emotion) and emotional prosody discrimination (i.e. judging if two vocal emotions were the same or different) in 9 to 15-year-old children (Tonks et al., 2007). Accuracy rates at an emotional naming task were 78% in 9-year-old children and 83% in 12 to 13-year-old children (Tonks et al., 2007). In adults, accuracy rates approximated 70-80% in vocal emotion identification tasks using speech (Baum & Nowicki, 1998) and non-speech (Maurage, Joassin, Philippot, & Campanella, 2007) stimuli. Research in similar tasks suggests that lower accuracy rates start to emerge across adulthood (Halpern, 1996) and gradually decreasing in older adults at an accuracy rate of about 60% (Roberts, McClure, & Nowicki, 1997).

In summary, knowledge on the development of vocal emotion recognition is limited compared to that of facial emotion recognition. No studies have examined the development of recognition of non-speech affective vocalisations, in particular, in children despite research indicating that linguistic information may have a distracting effect on children's judgement of emotional prosody (Morton & Trehub, 2001). In addition, no studies have systematically examined the role of intensity on recognition. Further evidence is essential to clarify the development of vocal emotion recognition at different intensity levels. Vocal expressions varying in intensity provide a more ecologically valid measurement of vocal emotion, as in real-life situations vocal emotions occur at different intensities (Baum & Nowicki, 1998). In addition, different intensity levels (i.e. high compared to low) reflect different levels of difficulty in emotion recognition and can capture subtleties in emotion recognition patterns in children (Pelc, Kornreich, Foisy, & Dan, 2006).

Chapter 2. Emotion Processing and Psychopathology

2.1 Chapter Overview

The present chapter will open with a brief description of the most common types of child behaviour problems, including hyperactivity, conduct problems and anxiety. The chapter will then discuss social dysfunctioning in children with behaviour problems. Subsequently, the relationship between social dysfunctioning and emotion processing in children with behaviour problems will be discussed. The chapter will review the most prominent theoretical models of emotion processing in children with behaviour problems. Although addressing both internalising and externalising behaviour problems, the chapter will adopt a special theoretical focus on externalising problems. Subsequently, evidence supporting facial and vocal emotion processing difficulties in children with behaviour problems will be presented. In line with the theoretical focus on externalising problems, this section will consist of an overview of evidence for emotion processing deficits in children with hyperactivity. In addition, Chapter 2 will review evidence for emotion processing biases and deficits in children with conduct problem and anxiety. Chapter 2 will end with a review of evidence on the socialisation of facial and vocal emotion processing.

2.2 Behaviour Problems in Children

2.2.1 Hyperactivity

Hyperactivity is a symptom dimension of Attention Deficit Hyperactivity Disorder (ADHD), a complex developmental disorder characterised by developmentally inappropriate levels of inattention, impulsivity and hyperactivity (APA; American Psychiatric Association, 2000). ADHD is divided into three subtypes: inattentive, hyperactive and combined type (APA, 2000), although children of the hyperactive subtype are likely to shift to a different subtype over time (Lahey, Pelham, Loney, Lee, & Willcutt, 2005). Hyperactive/impulsive symptoms include fidgeting, running around or talking excessively. Inattentive symptoms include difficulty sustaining attention, losing things and being easily distracted in daily activities. Children of ADHD combined type present symptoms of both hyperactivity and inattention (APA, 2000). Although ADHD is often diagnosed around the age of 8 (APA, 2000), it is a reliable and valid diagnosis in 2 to 5-year-olds (Egger, Kondo, & Angold, 2006; Wolraich, 2006). Early onset preschool hyperactivity can be a precursor to chronic ADHD (Sonuga-Barke, Auerbach, Campbell, Daley, & Thompson, 2005). ADHD is estimated to have a prevalence of about 3-7% in school-aged children (APA, 2000), depending on subtype and methods of assessment (Barkley, 2006) and 3.5 to 5.7% in preschoolers, with the hyperactive/impulsive subtype being more common than the inattentive type (Egger & Angold, 2006).

ADHD presents a complex causal structure (Coghill, Nigg, Rothenberger, Sonuga-Barke, & Tannock, 2005) with cognitive and motivational accounts being the most influential (review by Sonuga-Barke, Sergeant, Nigg, & Willcutt, 2008). ADHD has been characterised as a disorder of a set of executive functions (Pennington & Ozonoff, 1996), such as organisation, planning and working memory (Barkley, 1997a; review by Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). Motivational models suggest that ADHD extends beyond executive dysfunction (Castellanos, Sonuga-Barke, Milham, & Tannock, 2006; Sonuga-Barke, 2005) and highlight affective rather than cognitive components of the disorder. These models emphasise the different value that ADHD children attribute to different behavioural outcomes (Bitsakou, Antrop, Wiersema, & Sonuga-Barke, 2006; Sonuga-Barke, Taylor, Sembi, & Smith, 1992) and, as such, are more compatible with the study of emotion processing. There is also evidence that cognitive and motivational deficits, when combined, can explain more cases (Solanto et al., 2001) or different symptoms (Sonuga-Barke, 2002) of ADHD.

2.2.2 Oppositionality and Conduct Problems

Symptoms of ADHD often overlap with other externalising problems, such as Conduct Disorder (CD) and Oppositional Defiant Disorder (ODD) (Brown, 2009; Waschbusch et al., 2002). A recent meta-analytic review confirmed the high comorbidity between ADHD and ODD/CD in childhood and adolescence (Witthoft, Koglin, & Petermann, 2010).

ODD refers to a cluster of aggressive, noncompliant and defiant behaviours present by the age of 18 which interfere with children's function in multiple settings, such as school, home and the community, for at least six months (APA, 2000). ODD can manifest as temper tantrums, fights with other children, excessive arguing with adults, refusal to comply with rules and adult requests, frequent anger and explosive outbursts (APA, 2000).

The lifetime prevalence of ODD is estimated to be 10.2% (Nock, Kazdin, Hiripi, & Kessler, 2007). The comorbidity rate of ODD is estimated at around 30 to 60% in school-aged children with ADHD (Biederman, 2005; Jensen et al., 2001). Aggressive behaviours are present in at least 40-70% of school-aged children with ADHD (Barkley, 2003). Children with ADHD and ODD are more emotionally labile than children with ADHD symptoms alone (Sobanski et al., 2010). It is estimated that when untreated, about 52% of children with ODD will continue to meet the DSM-IV criteria up to three years later and about half of those will progress into CD (Lahey, Loeber, Quay, Frick, & Grimm, 1992).

CD is a condition at the severe end of a continuum of oppositional defiant behaviours (APA, 2000). CD is estimated to have a lifetime prevalence of 6-16% for males and 2-9% for females (Loeber, Burke, Lahey, Winters, & Zera, 2000; Maughan, Rowe, Messer, Goodman, & Meltzer, 2004). Children with CD often present verbal and physical aggression, lying, stealing and challenging behaviour (Essau, 2003; Loeber, Farrington, Stouthamer-Loeber, & Van Kammen, 1998). Adolescents with conduct disorder present atypical empathetic responses to others (deWied, Gispen-de Wied, & van Boxtel, 2010) and are at greater risk for developing antisocial personality disorder later in development (Lahey, Loeber, Burke, & Applegate, 2005). A number of factors may be responsible for the severity of behaviour problems in children with antisocial behaviour (Van Goozen & Fairchild, 2008). CD co-occurs with ADHD in at least 20% of children with ADHD (Biederman & Faraone, 2005). Nine- to thirteen-year-old boys with comorbid ADHD, ODD and CD were rated as angrier than other children, presented higher levels of aggression and were especially reactive to provocation from their peers (Waschbusch et al., 2002).

2.2.3 Anxiety and Depression

Externalising behaviour problems in children often co-occur with anxiety and depression (Jensen et al., 2001; Tannock, 2000). Affective lability has been associated with hyperactive symptoms in adults (Wender, 1995) and children (Conners, Erhardt, & Sparrow, 1999). High levels of anxiety have been found in clinical samples of children with ADHD (Power, Costigan, Eiraldi, & Leff, 2004). Longitudinal studies in population samples have linked teacher-perceived inattention and hyperactivity with a higher likelihood of belonging to a 'high anxiety' group over time (Duchesne, Larose, Vitaro, & Tremblay, 2010). In addition, reactive aggression at home and at school was related to parent and teacher-rated child anxiety and shyness (Epkins, 1995; Kolko, Baumann, Bukstein, & Brown, 2007; Vitaro & Brendgen, 2005) and elevated risk for developing anxiety (review by Zoccolillo, 1992). Emotion dysregulation has been shown to be predictive of oppositional defiant behaviours (Stringaris, Maughan, & Goodman, 2010). Other studies have shown that conduct problems at age 10 could predict depressive symptoms in early adulthood (Mason et al., 2004).

Childhood depression is characterised by low mood and dysthymia (Kovacs & Devlin, 1998) and is associated with an attentional bias toward negative or sad emotional stimuli (Vasey & MacLeod, 2001). Anxiety emerges in childhood and forms part of children's typical development (Kendall & Suveg, 2006). Fears and worries play an adaptive function in typical development (Sroufe, 1996). However, developmentally inappropriate behaviours, such as persistent fears, associated with clinical levels of anxiety can have devastating effects on children's daily functioning (APA, 2000). Anxiety occurs in 2-15% of children and adolescents in clinical groups (review by Rapee, Schniering, & Hudson, 2009) and about 5% in population samples of 9- to 10-year-old children, with prevalence rates lower in boys than girls (Costello, Mustillo, Erkanli, Keeler, & Angold, 2003). Clinical levels of anxiety are present during the preschool years (Egger & Angold, 2006) and follow a stable developmental course throughout childhood (review by Weems, 2008). Information processing biases have been associated with childhood anxiety (review by Hadwin & Field, 2010) and can be predictive of anxiety symptoms (Warren, Emde, & Sroufe, 2000). Temperament and shy-inhibited behaviour have also been associated with the development of anxiety in children (Feng, Shaw, & Silk, 2008; Fox, Henderson, Marshall, Nichols, & Ghera, 2005).

2.2.4 Social Dysfunctioning in Children with Behaviour Problems

Childhood behaviour problems have a negative impact on many domains of child development including cognitive, academic and social outcomes. Problems in academic performance at school are frequent in children with hyperactivity (Mannuzza, Klein, & Moulton, 2002; McGee, Prior, Williams, Smart, & Sanson, 2002; Rutter, Tizard, & Whitmore, 1970) and anxiety (Owens, Stevenson, Norgate, & Hadwin, 2008). Children with persistent hyperactivity presented occupational, educational and financial difficulties as adults due to emotional impulsiveness (Barkley & Fischer, 2010).

Social dysfunctioning represents a major functional impairment in some children with hyperactivity (Greenbaum, Stevens, Nash, Koren, & Rovet, 2009; review by Nijmeijer et al., 2008; Nixon, 2001). Hyperactive children presented significantly lower social skills compared to children with other disabilities (Fussell, Macias, & Saylor, 2005) and this considerably limited their access to educational and social opportunities (Landau & Moore, 1991). Social dysfunctioning can manifest as physical and verbal aggression, controlling behaviour, and rule violations (Erhardt & Hinshaw, 1994; Mikami & Hinshaw, 2003) or hyperactive/impulsive behaviours such as interrupting other children's play and running around (Barkley, 1997b), whereas social passivity and anxious social behaviour is more common in children with inattentive symptoms (Maedgen & Carlson, 2000). Children with hyperactivity, both boys and girls (Biederman, 2005), appeared to be more rejected by their peers (Hoza, 2007; Pelham & Bender, 1982), more disliked by other children (Buhrmester, Whalen, Henker, MacDonald, & Hinshaw, 1992) and have fewer dyadic friends (Gresham, MacMillan, Bocian, Ward, & Forness, 1998; Mikami, 2010) compared to typical children. Vicious cycles of rejection by peers leading to poor social skills, which in turn predicted peer rejection (Murray-Close et al., 2010) contributed to circular processes of perpetuating social problems in these children (Hoza, 2007).

In addition, social problems in children with hyperactivity have high prognostic relevance. For instance, difficulties in establishing and maintaining friendships were frequent among adolescents and young adults with ADHD (Bagwell, Molina, Pelham, & Hoza, 2001; Young, Heptinstall, Sonuga-Barke, Chadwick, & Taylor, 2005). Furthermore, social dysfunctioning in ADHD is very difficult to treat. For example, despite medication bringing the same degree of improvement of social functioning as social skills interventions in children with hyperactivity (Abikoff et al., 2004; Van der Oord et al., 2005), medication cannot increase positive social behaviour which is crucial in normalising peer status in this group of children (Hoza et al., 2005; Whalen & Henker, 1991).

Factors that contribute to social impairment in children with hyperactivity remain unclear (Hoza, 2007). It has been proposed that social dysfunctioning may be inherent to some core dimensions of ADHD such as inattention, impulsivity or deficient self-control. For example, children with hyperactivity may not lack 'knowledge' regarding affective display rules but, instead, have difficulty in regulating emotional reactions in response to social rules or context demands and inhibit inappropriate behaviour (Barkley, 1997b). There is empirical evidence that impulsive-hyperactive boys displayed greater disinhibition and were less effective at emotion regulation (Walcott & Landau, 2004). Further research has linked 'performance' difficulties and deficient emotion self-regulation to combined type ADHD whereas deficits in social knowledge (i.e. awareness of social rules) were related to inattentive symptoms in children (Maedgen & Carlson, 2000).

Recently, the assumption that social dysfunctioning in these children is a direct consequence of core ADHD dimensions has been challenged. In contrast, it has been suggested that biased perception of social cues and deficits in social information processing may explain social skills difficulties in this group of children (McQuade & Hoza, 2008). Socio-cognitive skills were an important moderator for treatment efficacy during social skills training for children with hyperactivity (De Boo & Prins, 2007). Also, executive functions, such as memory, did not mediate the relationship between inattention and social adjustment (Huang-Pollock, Mikami, Pfiffner, & McBurnett, 2009). Finally, differences in social adjustment among ADHD subtypes remained stable even after controlling for IQ, reading achievement and comorbid disruptive behavior disorders (Huang-Pollock et al., 2009). In summary, further research is necessary to clarify the social profiles of children with hyperactivity.

An adjacent question regards social dysfunctioning in children with symptoms of ODD or CD. Difficulties with interpersonal relationships and social interactions are common in children with conduct problems (Patterson, 1986). Social dysfunctioning can often manifest as aggressive behaviour, although in a minority of children, hyperactive and impulsive behaviours were associated with peer rejection independently of aggressive behaviour (Wheeler & Carlson, 1994). Aggressive behaviour and oppositionality can lead to lower sociometric status (Hinshaw & Melnick, 1995) and exacerbate the social impairment already present in children with hyperactivity, such as maladaptive interpersonal coping (Hampel, Manhal, Roos, & Desman, 2008) or dysfunctional family relations (Barkley, Anastopoulos, Guevremont, & Fletcher, 1992). Despite the benefits of early social skills interventions in children with hyperactivity (Chang, Tsou, Shen, Wong, & Chao, 2004), children with hyperactivity co morbid with conduct problems seemed to benefit less from such interventions compared to children with hyperactivity alone (Antshel & Remer, 2003). Finally, in children with anxiety, behavioural inhibition limited opportunities to socialise, which in turn, resulted in a negative self-appraisal about lack of social skills, which perpetuated anxiety over time (Rubin & Burgess, 2001). Similar research has shown that children with anxiety had a smaller network of close friends. Lack of positive peer interactions further contributed to anxiety and social withdrawal in this group of children (Greco & Morris, 2005). Low friendship quality and low peer acceptance have been found to predict symptoms of child depression and loneliness in children (Nangle, Erdley, Newman, Mason, & Carpenter, 2003).

In summary, social adjustment problems in children with behaviour problems can have debilitating effects on children's daily functioning, however, the extent to which such difficulties result from inattention/impulsivity or a socio-cognitive deficit remains unclear.

2.2.5 Social Dysfunctioning and Emotion Processing

It has recently been suggested that social skills difficulties in children with behaviour problems may stem from poor emotion understanding and, in particular, inaccurate perception of emotion from non-verbal cues (Pelc et al., 2006).

Longitudinal studies have found that difficulties in early steps of social information processing (i.e. decoding non-verbal cues) in the preschool years could predict externalising behaviour problems at 16 years (Lansford et al., 2006). Lower accuracy in recognising anger and sadness from facial expressions and lack of awareness of such errors were linked to higher levels of interpersonal difficulties in hyperactive school-aged children (Pelc et al., 2006). Anger misrecognition was positively related to teacher and peer rated social skills in children at risk for hyperactivity (Kats-Gold, Besser, & Priel, 2007). Finally, adults with ADHD who presented receptive deficits of non-verbal emotional cues viewed themselves as less competent at social skills, such as emotional expressivity, emotional sensitivity and emotional control (Friedman et al., 2003).

Research has consistently shown that social competence was positively associated with accuracy at recognising not only facial but also vocal emotional expressions in preschoolers (Verbeek, 1996) and school-aged children (Mitchell, 1995). Beyond accuracy, information processing biases, such as bias to angry facial expressions, have been linked with externalising behaviour problems (Barth & Bastiani, 1997) and anxiety (review by Hadwin & Field, 2010). The above findings highlight the importance of sensitivity to others' emotional displays from non-verbal cues in the development of social skills in children who present or are at risk for behaviour problems.

2.3 Emotion Processing and Behaviour Problems

2.3.1 Theoretical Models of Emotion Processing in Children with Behaviour Problems

From the existing literature, it is not clear whether poor attention/impulsivity or an actual emotion processing deficit accounts for the emotion processing difficulties. There are alternative explanations for the finding that children with behaviour problems present such deficits. Evidence is currently divided between a 'social perception' hypothesis proposed by socio-cognitive approaches and a 'general cognitive dysfunction' hypothesis proposed by cognitive-behaviour models. The section that follows reviews models in children with externalising behaviour problems, such as hyperactivity, in a generic sense and including studies in ADHD.

On the one hand, it has been suggested that emotion recognition difficulties constitute part of a non-specific deficit in attentional processing, rather than a deficit specific to emotion, and that such deficits are closely tied to core ADHD symptoms (Cadesky, Mota, & Schachar, 2000), thus rendering deficits in social cognition a secondary dysfunction of inattention and impulsiveness. According to this hypothesis, difficulties in recognising expressions portraying emotion may reflect an inability to selectively attend to emotional information displayed by adult faces and voices or an inaccurate impulsive style of processing. For example, Fine and colleagues (2008) compared 30 children with hyperactivity and healthy controls on an emotion perception task based on videos with social interactions. The study found that hyperactive children performed worse than controls, however, inattention symptoms and IQ accounted for 52% of the variance in perception of emotion cues in hyperactive children (Fine, Semrud-Clikeman, Butcher, & Walkowiak, 2008). This is compatible with adult research showing that emotion recognition abilities were more adversely affected by inattentive than hyperactive symptoms (Miller, Hanford, Fassbender, Duke, & Schweitzer, 2010).

In a similar study (Sinzig, Morsch, & Lehmkuhl, 2008) performance at sustained attention and inhibition tasks was associated with emotion recognition accuracy from facial expressions and eye pairs in 6- to 18-year-old children with hyperactivity compared to typical children. Also, IQ contributed to between group differences in accuracy. These findings suggest that emotion recognition deficits in children with hyperactivity may be due to inattention or poor inhibitory control. More recent research (Semrud-Clikeman, 2010) has provided confirmatory evidence for this hypothesis. Also, facial and vocal emotion processing difficulties in 6- to 12-year-olds with hyperactivity were not specific to emotion but spanned across areas such as non-verbal and verbal attention, working memory and visuospatial abilities (Corbett & Glidden, 2000). When attention performance was assessed alongside a facial emotion recognition task, attention errors accounted significantly for the emotion recognition difficulties in children with hyperactivity (Shin, Lee, Kim, Park, & Lim, 2008). Additional support for an 'attention dysfunction' hypothesis derives from research showing atypical visual scanpaths to facial emotional expressions in hyperactive participants (review by Marsh & Williams, 2006). Similarly, attention on the eye region of a face normalised emotion recognition deficits in children with conduct problems (Dadds et al., 2006; Glaser et al., 2010).

The view that emotion processing difficulties in children with externalising behaviour problems may be due to inattention and higher-order executive functions rather than lower-order emotion specific perceptual abilities seems to be compatible with cognitive behaviour models of hyperactivity (Barkley, 1997a). Such models suggest that children with hyperactivity fail to attend to emotion cues and for this reason they cannot perceive them accurately. According to this model, children do not present 'knowledge' difficulties but 'performance' difficulties (Barkley, 1997a; Jensen & Rosen, 2004). A related explanation would be that these children *do* attend to emotional cues, but they present a tendency to respond quickly and impulsively. This disinhibited, impulsive style of processing emotional information is consistent with theories suggesting general difficulties in self-regulation of responding (Oosterlaan & Sergeant, 1996) and regulating response inhibition (Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004) in children with hyperactivity, although, this hypothesis has not been tested systematically in emotion processing tasks with a few exceptions (Sinzig et al., 2008).

On the other hand, alternative theoretical models propose that maladaptive social information processing may account for emotion processing biases in children with behaviour problems (Crick & Dodge, 1996; Dodge, 1980; Dodge, Bates, & Pettit, 1990). According to social information processing theory, emotion processing biases refer to socio-cognitive schemata which have an impact on children's social behaviour through social perception processes (Crick & Dodge, 1994). These theories suggest that children's responses to social situations depend on a sequence of information processing steps, including decoding relevant social cues, making attributions about what motivates others' behaviour, selecting a desired goal in a social situation, thinking of potential responses to a situation, evaluating responses and, finally, enacting responses in form of actual behaviour (Crick & Dodge, 1994; Dodge, Pettit, McClasky, & Brown, 1986). For example, children who infer anger in ambiguous situations would tend to attribute hostile intentions to others' behaviour and display aggressive behaviour (Dodge, Bates, et al., 1990; Schultz, Izard, & Ackerman, 2000).

Although, this framework has been linked primarily to anxiety and conduct problems, research has suggested that specific socio-cognitive problems may also affect children with hyperactivity (Matthys, Cuperus, & Van Engeland, 1999). For example, hyperactive-aggressive boys displayed hostile interpretive biases, response decision biases, and encoding biases relative to typical children (Milich & Dodge, 1984; Murphy, Pelham, & Lang, 1992). These studies, however, also acknowledged that cognitive mechanisms such as inattention or impulsivity may account for such deficits. The authors highlighted that it is possible that hyperactive–aggressive boys were likely to make more errors in their processing of social information than typical children and, therefore, have a smaller pool of social information to base their social judgements. In fact, hyperactive children recalled fewer social cues, from a pool of socially relevant cues, were less likely to integrate them into interpretations of social events (Milch-Reich, Campbell, Pelham, Connelly, & Geva, 1999) and generated fewer responses to a problem (Matthys et al., 1999).

More recent research has found that 6- to 12-year-old children with hyperactivity did not differ from controls in hostile attribution biases, suggesting that such biases may be specific to aggression rather than hyperactivity (King et al., 2009). However, hyperactive children generated more hostile responses to peer provocations scenarios than controls when on medication, implying that hyperactivity may be linked to some social information processing difficulties (King et al., 2009), although a limitation of the above study was that some children also had comorbid conduct problems. Difficulties in teacher-rated social perception were found in 6- to 10-year-olds with hyperactivity comorbid with learning disabilities when compared to regular education children (Hall, Peterson, Webster, Bolen, & Brown, 1999; Sprouse, Hall, Webster, & Bolen, 1998), although potential teacher bias may have confounded these results.

Further support for the hypothesis that children with behaviour problems may present a specific emotion processing difficulty derives from a number of studies which have directly controlled for the influence of other mediating factors. For example, Da Fonseca and colleagues (2009) have compared the performance of 27 school-aged children with hyperactivity with that of healthy controls on a facial emotion recognition task and a control object recognition task. Results showed that hyperactive children presented lower accuracy at the emotion recognition but not the object recognition task suggesting that general difficulty to attend to relevant stimuli or inhibit responses did not account for the emotion processing deficits. In addition, performance was unrelated to general IQ and ODD symptoms (Da Fonseca, Seguier, Santos, Poinso, & Deruelle, 2009).

In a similar study, Yuill and Lyon (2007) found that 7- to 11-year-old hyperactive children presented lower accuracy than controls only at an emotion recognition task, consisting of matching facial emotion expressions to situations, but did not differ in accuracy from controls at a non-emotional task. This was the case even after an inhibitory scaffolding procedure (i.e. provide support for children during the emotion task). Findings suggest that since emotion processing was not improved after the inhibitory scaffolding, children with hyperactivity may present a selective difficulty in processing emotion rather than a general deficit in attending to emotional stimuli or inhibiting responses (Yuill & Lyon, 2007).

Findings in support of a specific emotion perception deficit also derive from the adult literature. For example, Rapport and colleagues (2002) compared 28 ADHD adults and healthy controls at a facial affect task and a non-emotion animal categorisation task. ADHD adults were less accurate and slower than controls only at the facial affect task but did not differ significantly from controls on either accuracy or response times at the non-emotion task. In addition, there were no differences between the groups in general face recognition skills and visual processing abilities (Rapport, Friedman, Tzelepis, & Van Voorhis, 2002).

Beyond facial emotion processing, there is some preliminary evidence that vocal emotion processing in hyperactive children is not related to general cognitive abilities. For example, children with hyperactivity were more accurate to recognise vocal anger than controls, even after controlling for IQ, gender and conduct problems (Manassis, Tannock, Young, & Francis-John, 2007). Beyond this study by Manassis and colleagues (2007), however, studies directly examining vocal emotion processing in regards to the hypothesis of a specific perceptual bias or deficit towards vocal anger remain limited.

The study of emotion-specific difficulties in children with behaviour problems seems to be more compatible with motivational accounts of hyperactivity (Sonuga-Barke, 2005; Sonuga-Barke et al., 1992). There is empirical evidence that differences in social cognition and theory of mind can contribute to emotion recognition difficulties in children with hyperactivity (Buitelaar, Van der Wees, Barneveld, & Van Der Gaag, 1999). Similarly facial emotion processing was unrelated to executive response inhibition during a stop signal task (Blaskey, Harris, & Nigg, 2008). It is also possible that, whatever the primary cause (i.e. inattention/impulsivity) of emotion processing deficits might be, socio-cognitive difficulties may become part of a vicious circle, further hindering successful social interactions in children with behaviour problems (Yuill & Lyon, 2007).

Finally, it has been proposed that lower accuracy (i.e. deficits) can be a marker of 'cognitive deficiency' and more likely to characterise children with inattentive or impulsive symptoms, whereas misinterpretation among emotions (i.e. biases) can be interpreted as 'cognitive distortion' more common in children with conduct problems (Cadesky et al., 2000). For example, children with hyperactivity made emotion recognition errors that were random in nature whereas children with conduct problems showed a tendency to misinterpret emotions, such as incorrectly interpreting happy and fearful expressions as angry (Cadesky et al., 2000). Recent studies have also shown that symptoms of conduct problems were unrelated to accuracy in facial emotion recognition tasks (Woodworth & Waschbusch, 2008). These findings raise important questions regarding distinct emotion processing profiles (deficits versus biases) in children with different types of externalising behaviour problems (hyperactivity versus conduct problems).

In summary, cognitive-behaviour models have suggested that emotion processing difficulties in children with behaviour problems result from general inattention or impulsiveness. On the other hand, socio-cognitive models have argued in favour of emotion-specific difficulties. Alternative intepretations suggest that inattention/impulsivity and socio-cognitive difficulties may interact to hinder successful emotion processing. Finally, it is possible that emotion processing difficulties may take different forms in children with different forms of psychopathology (Cadesky et al., 2000).

2.3.2 Evidence for Emotion Processing Deficits in Children with Hyperactivity

A growing body of work has provided empirical evidence for emotion processing difficulties in children with hyperactivity.

It has been found that children with hyperactivity show difficulties in developing insight into other people's emotions and understanding emotional information from facial cues. For example, Singh and colleagues (1998) found that children with hyperactivity presented a 74% overall recognition accuracy at a facial emotion recognition task which was lower than the mean accuracy of 89% reported in an archival control group (McAlpine, Singh, Kendall, & Ellis, 1992). Children at risk for hyperactivity presented more overall errors and longer reaction times in emotion recognition tasks often confusing angry, happy and sad faces with fearful faces (Kats-Gold et al., 2007). Also, hyperactive children had difficulty compared to typical children in correctly identifying facial expressions of anger at high (i.e. 70%) intensity and sadness at both high (i.e. 70%) and low (i.e. 30%) intensities (Pelc et al., 2006).

School-aged children with hyperactive symptoms presented lower accuracy across a number of emotions compared to typical children, not only at facial expressions identification tasks (Corbett & Glidden, 2000) but also in a range of similar tasks such as indicating how the characters felt in videos displaying social interactions (Fine et al., 2008), matching schematic faces to contextual social situations (Da Fonseca et al., 2009), matching emotional faces to brief emotional scenarios (Yuill & Lyon, 2007), recognising emotions from eye pairs (Sinzig et al., 2008) and identifying facial expressions across a range of presentation modes including cartoon, real life portrayals, static and dynamic (i.e. video clip) expressions (Boakes, Chapman, Houghton, & West, 2008).

Although the above studies have focused on school-aged children, recent research has shown that decreased accuracy for sadness perception from expressive and situational cues (i.e. a puppet task) was linked to externalising behaviour problems in preschoolers (Martin, Boekamp, McConville, & Wheeler, 2010). Furthermore, emotion processing deficits, such as fear recognition, persisted in a clinical population of adolescents (Gádoros, Németh, Ricsóy, Szádvári, & Halász, 2010) and adults (Miller et al., 2010) with ADHD. In particular, adults with hyperactivity have been found to be less accurate and slower to recognise fearful, angry, happy and sad facial expressions (Rapport et al., 2002) and use fewer affect related words in free recall information tasks from film clips with social context (Friedman et al., 2003), compared to healthy controls. Deficits in recognition of happy and sad facial expressions have been found in adults with subclinical symptoms of ADHD (Fields, 2008).

In contrast to the above studies showing differences between children with behaviour problems and typical children, other studies have not found such differences. Children with hyperactivity compared to typical children did not differ in facial emotion labelling errors (Guyer et al., 2007), recognising emotions from tone of voice (Hall et al., 1999), identifying angry, happy and sad facial expressions (Boakes et al., 2008) and recognising emotions from facial, vocal, verbal expressions and expressions combining these three modalities (Egan, Brown, Goonan, Goonan, & Celano, 1998). A failure to replicate deficits in facial emotion recognition in children with ADHD symptoms was also evident in other studies (Norvilitis, Casey, Brooklier, & Bonello, 2000; Shapiro, Hughes, August & Bloomquist, 1993) and children with hyperactivity comorbid with learning disabilities (Sprouse et al., 1998). Children with comorbid hyperactivity and conduct problems were as accurate as controls in recognising angry, happy, sad and fearful emotions from adult and child faces (Cadesky et al., 2000). In addition, 6- to 12-year-olds with hyperactivity showed competent performance at social cognition tasks including videos displaying social interactions with peers (Whalen, Henker, & Granger, 1990).

In summary, the literature is currently inconsistent regarding links between facial emotion processing and child hyperactivity. This inconsistency may partly be explained by variability in methodological paradigms, including different types of stimuli (i.e. facial photographs, video clips, schematic faces) and tasks (i.e. emotion identification, matching tasks, and matching stories to facial photographs) as well as heterogeneity of behaviour problems in children (i.e. hyperactivity, conduct problems).

While the above research has highlighted the importance of facial emotion processing in children with behaviour problems, the role of vocal emotion processing has been particularly understudied. This is surprising given that sensitivity to emotion from vocal cues has consistently been associated with children's social competence (Baum & Nowicki, 1998; Rothman & Nowicki, 2004). Vocal expressions provide a more ecologically valid tool for the assessment of emotion processing in children with hyperactivity and other behaviour problems for a number of reasons.

First, vocal expressions (i.e. vocal anger) may be more relevant for the study of externalising problems because they are particularly salient punishing social signals (Banse & Scherer, 1996; Scherer, Schorr, & Johnstone, 2001), with regular occurrence in day-to-day social interactions and the ability to capture attention from a greater distance compared with facial expressions, as is often the case in interactions with caregivers (Fernald, 1993). Second, children with hyperactivity may utilise alternative (i.e. auditory) channels to perceive affective information, partly due to difficulties in processing such information from visual channels. For example, eye-movement research has shown shorter fixations to pictorial stimuli in children with hyperactivity (Karatekin & Asarnow, 1999). Similar studies have found decreased number and duration of fixations and more extensive or random scanning of facial emotional expressions in individuals with ADHD compared to controls (Marsh et al., 2000; review by Marsh & Williams, 2006). Vocal expressions can communicate emotion independently of viewing condition and this renders them particularly salient signals.

One line of research has reported deficits in vocal but not facial emotion processing in children with externalising behaviour problems. For instance, Norvilitis and colleagues (2000) found lower accuracy in vocal but not facial emotion recognition (i.e. angry, happy and sad) in 10-year-old children with hyperactivity and these deficits were the best predictor of psychopathology in children. Shapiro and colleagues (1993) showed that 8-to

11-year-old children with hyperactivity did not present deficits in facial emotion recognition but, instead, they presented difficulties in matching emotional prosody to content and facial expressions. It should be noted, however, that the above study employed complex (i.e. matching) tasks tapping on higher-order executive functions rather than lower-order perceptual processes. In a relevant study 7- to 10-year-old children with hyperactivity and learning disabilities presented lower accuracy than controls in vocal but not facial emotion recognition, an effect not present in children with hyperactivity alone (Hall et al., 1999). However, this study in children with learning disabilities did not control for receptive language skills which was critical given the linguistic content of the stimuli. Hyperactive children presented higher accuracy for vocal (but not facial) anger compared to controls, even after controlling for IQ and conduct problems, which was interpreted as a perceptual bias to vocal anger (Manassis et al., 2007).

In addition, some investigations have shown that emotion processing difficulties in children with behaviour problems spanned across facial and vocal modalities. For example, Corbet and Glidden (2000) found that 7- to 12-year-olds with hyperactivity were less accurate in identifying the emotion portrayed in both facial expressions and tone of voice across a range of emotions. Also, adults with hyperactive symptoms were less accurate than controls in recognising emotions from both faces and voices (Rapport et al., 2002). A recent study using a puppet task with animated facial expression and tone of voice found reduced accuracy in sadness perception in preschoolers with externalising behaviour problems (Martin et al., 2010). This study, however, assessed emotion understanding from situational cues (stories) rather than an experimental face/voice recognition tasks and included a small number of trials.

A last body of literature reported no differential effects between facial and vocal emotion processing on child behaviour. Cadesky and colleagues (2000), for example, examined both facial and vocal emotion processing in children with behaviour problems and reported no differential effects of facial and vocal processing on children’s symptoms. Similar findings derived from two studies with children presenting ADHD comorbid with conduct problems (Guyer et al., 2007) and learning disabilities (Sprouse et al., 1998). In summary, current knowledge on vocal emotion processing in children with externalising behaviour problems remains limited and inconsistent.

A reason accounting for the lack of research in this area may be the absence of methodologically suitable tools for the assessment of vocal emotion perception in young children. No studies have examined this issue perhaps because of difficulties involved in developing a validated battery of age-appropriate stimuli. A second limitation is the paucity of research in vocal emotion perception in preschoolers with behaviour problems, as most studies so far have focused on school-aged children. This is important because it can throw further light on the developmental origins of vocal emotion perception difficulties. Third, existing studies have not taken into account the role of comorbidity in children's vocal emotion processing. For instance, selective impairments in processing vocal expressions have been found in children with conduct problems (Stevens, Charman, & Blair, 2001), however, the extent to which hyperactivity and conduct problems relate differentially to such deficits remains unclear. Further work is required to address these limitations.

2.3.3 Evidence for Emotion Processing Difficulties in Children with Conduct Problems

The above literature has provided evidence for links between hyperactivity and emotion processing deficits. A separate line of research has highlighted emotion processing difficulties, in terms of both biases and deficits, in children with conduct problems.

Emotion processing biases in children with conduct problems have more often been studied in the context of social information processing theoretical frameworks. Although emotion processes have not explicitly been part of the original social information processing model (Crick & Dodge, 1994), more recent theoretical perspectives (Lemerise & Arsenio, 2000) have integrated emotion processes in the above model. For instance, encoding and interpretation of social cues may involve other people's emotions, which may trigger emotion-specific goals and responses. Emotion processing biases (i.e. systematic errors in children's responses) are informative because they reflect children's tendency to over-identify particular emotions or to attribute a particular emotion when uncertain of the correct response. For example, whereas anger perception accuracy would demonstrate the ability to correctly identify anger, anger perception bias would indicate a systematic tendency to attribute anger to an expression in the absence of concordant cues. Emotion processing biases can be more important than recognition accuracy in predicting social behaviour, because they remain more stable over time (Barth & Bastiani, 1997).

Hostile attribution biases, such as a tendency to interpret cues as hostile or attribute hostile intentions to others' behaviour, often characterise children with aggressive behaviour and conduct problems (Dodge & Coie, 1987; Dodge, Price, Bachorowski, & Newman, 1990; Matthys et al., 1999). Research has shown that aggressive boys presented anger attribution biases in facial expression recognition tasks (Schultz, Izard, & Bear, 2004), reported more anger during encoding of social situations, generated more aggressive responses and evaluated these responses more positively compared to non-aggressive boys (de Castro, Merk, Koops, Veerman, & Bosch, 2005). Higher bias to angry facial expressions was negatively associated with socio-metric status and had predictive value for higher teacher-reported behaviour problems during the preschool years (Barth & Bastiani, 1997). Increased anger perceptual biases in the third grade could predict higher aggressiveness in fifth grade children (Fine, Trentacosta, Izard, Mostow, & Campbell, 2004). Similarly, better recognition of angry compared to happy faces predicted teacher-reported hyperactivity and conduct problems in adolescents (d'Acremont & Van der Linden, 2007). Early and late steps of information processing biases, such as perception and evaluation of social cues, had additive effects on exacerbating externalising symptoms in children (Lansford et al., 2006) and interacted with peer rejection and aggressive behaviour in a cumulative way over time (Pettit, Lansford, Malone, Dodge, & Bates, 2010).

Beyond biases, emotion processing deficits have also been reported in developmental populations with conduct problems. For instance, children with psychopathic tendencies compared to controls made more errors in detecting fearful and sad facial expressions (Blair, Colledge, Murray, & Mitchell, 2001; Marsh et al., 2008) and sad vocal tone (Stevens et al., 2001). However, the latter study involved a small sample size of children with conduct problems (N=9). Impaired recognition of vocal emotion (i.e. fear) was present in psychopathic adults (Blair et al., 2002). Recent research has revealed impaired recognition of anger and disgust from facial expressions in male (Fairchild, Van Goozen, Calder, Stollery, & Goodyer, 2009) and female (Fairchild, Stobbe, Van Goozen, Calder, & Goodyer, 2010) adolescents with conduct disorder. Also, adolescents with conduct disorder presented a tendency to evaluate negative pictures less aversively (Herpertz et al., 2005) and affective (i.e. pleasant, unpleasant) stimuli as less arousing (Herpertz et al., 2008). Adolescents with conduct disorder also showed lower electrodermal responses to affective stimuli (Herpertz et al., 2005). Similarly, children who reported decreased emotional arousal to affective pictures presented higher levels of conduct problems at 1-year follow-up (Sharp, Petersen, & Goodyer, 2008).

It is important to note that emotion processing deficits in many of the aforementioned studies were examined in relation to psychopathic personality traits (i.e. callousness and lack of empathy), which are frequent in children with conduct problems (Frick, O'Brien, Wootton, & McBurnett, 1994). Children and adolescents with psychopathic tendencies, for example, showed reduced sensitivity to fearful facial expressions in behavioural (Blair, Budhani, Colledge, & Scott, 2005; Dadds, El Masry, Wimalaweera, & Guastella, 2008; Dadds et al., 2006) and functional neuro-imaging (Jones, Laurens, Herba, Barker, & Viding, 2009) studies. This pattern of findings has been termed ‘deafness to fear’ (Blair et al., 2005) and ‘fear blindness’ (Dadds et al., 2008). Earlier work has associated such deficits in psychopathic individuals with insensitivity to punishment (Hare, 1970). Recent neurocognitive models have suggested that representations of acts that cause to others harm or pain (i.e. fearful or sad signals) do not trigger violence inhibition mechanisms in children with psychopathic tendencies (Blair, 2001). Selective impairments in the recognition of sadness from facial expressions in children with conduct problems has been suggested to reflect lower empathetic responding to distress cues of others (de Wied et al., 2010).

2.3.4 Evidence for Emotion Processing Biases in Children with Anxiety

A rich body of empirical research has demonstrated the utility of social information processing theories for understanding maladaptive behaviour in children with anxiety. Research has highlighted the impact of information processing biases across development in childhood anxiety (review by Hadwin & Field, 2010; Hadwin, Garner, & Perez-Olivas, 2006; Waters, Mogg, Bradley, & Pine, 2008), as in adult populations with internalising symptoms (Garner, Baldwin, Bradley, & Mogg, 2009; Mogg, Garner, & Bradley, 2007).

Anxiety in children has been linked to interpretation biases. For example, increased threat interpretation of pictorial homographs/homophones has been found in 7- to 9-year-old children with high levels of trait anxiety (Hadwin, Frost, French, & Richards, 1997). Similar research has shown general emotional reasoning biases and increased threat perception, such as judging a situation as more dangerous, in children with anxiety (Muris, Vermeer, & Horselenberg, 2008).

Another line of research has provided evidence for attentional biases to threat in childhood anxiety (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van, 2007). It has been suggested that high anxious children lack the ability to inhibit attention to threat, an ability which follows a typical developmental course during childhood (Kindt & Van Den Hout, 2001). For example, anxious children tended to present attentional biases toward angry faces (Perez-Olivas, Stevenson, & Hadwin, 2008) and away from fearful faces (Stirling, Eley, & Clark, 2006). More recent research has shown an attentional bias towards angry faces across short and long exposure durations in children with higher levels of anxiety, an effect which was not present with happy faces (Waters, Kokkoris, Mogg, Bradley, & Pine, 2010). These findings are consistent with studies on visual search for emotional faces in children with self-reported anxiety (Hadwin et al., 2003) and Go-NoGo tasks with emotional faces in children with paediatric anxiety disorders (Waters & Valvoi, 2009). Increased levels of anxiety in late childhood have also been associated to decreased ability to discriminate facial expressions in general (Richards, French, Nash, Hadwin, & Donnelly, 2007).

In summary, the study of information processing biases in childhood is useful because it can help identify early markers for the development of anxiety (Vasey & MacLeod, 2001). Existing research in childhood anxiety has focused on facial stimuli and it is not know whether the above biases would generalise to vocal emotional expressions.

2.3.5. The Role of Comorbidity in Emotion Processing Deficits and Biases

The literature reviewed above raises important questions regarding the role of comorbidity in disentangling mechanisms underlying emotion processing deficits and biases in children with a range of behaviour problems.

Comorbidity can play an important role in understanding patterns of emotion processing, as children with externalising and internalising problems may develop different forms of emotion processing difficulties. For example, children with disruptive behaviour problems more often correctly identified anger when matching the emotion depicted in a story to facial expressions, whereas children with mood disorders more often identified sadness (Ellis et al., 1997). The findings suggest that different emotions (anger versus sadness) may play a different role in mechanisms underlying different types of psychopathology (externalising versus internalising). Similar research has shown that adolescents with antisocial behaviour presented impaired anger recognition, whereas emotional problems were linked to better recognition of anger but lower recognition of neutral faces (Leist & Dadds, 2009). Children with comorbid anxiety and hyperactivity showed lower sensitivity to vocal anger compared to children with either anxiety or hyperactivity alone (Manassis et al., 2007). Social information processing biases can also relate differentially to different manifestations of child problem behaviour. For example, children with conduct problems displayed hostile behaviours following interpretation of threat, whereas those with anxiety presented avoidant behaviours (Barrett, Rapee, Dadds, & Sharon, 1996)

Limited experimental research has directly compared different psychopathological groups of children in facial and vocal emotion recognition paradigms assessing accuracy and bias. The argument that different mechanisms may underlie emotion processing in children with different psychopathological profiles has not been systematically examined. Future studies should examine independently children with hyperactivity, conduct problems and anxiety to elucidate underlying emotion processing mechanisms in distinct psychopathological conditions.

2.4 The Role of Parent Characteristics in Children's Emotion Processing

Previous research has examined emotion processing in children with behaviour problems in isolation from the social context. A supplementary aim of the present thesis was to explore the influence of the social environment on children's emotion processing. Following models of developmental psychopathology (Cicchetti & Rogosch, 2002; Rutter & Sroufe, 2000), the present research explored the origins of emotion processing difficulties in child psychopathology in a parenting context (Creswell, Murray, Stacey, & Cooper, 2011).

Parents have an organised set of feelings and thoughts about their own emotions which may influence the way they respond to the emotions of their children (Gottman, Katz, & Hooven, 1997). Recent research supports links between internalising parental psychopathology and social information processing biases in children (Perez-Edgar, Fox, Cohn, & Kovacs, 2006). Maternal depressive symptoms have generally been associated with lower emotion knowledge in the child (Greig & Howe, 2001). For example, infants of depressed mothers showed atypical face processing and a tendency not to look at sad compared to happy faces (Field, Pickens, Fox, Gonzalez, & Nawrocki, 1998). Similarly, daughters of mothers at elevated risk for depression, but not control daughters of never-disordered mothers, selectively attended to negative (i.e. sad) facial expressions whereas control daughters selectively attended to positive (i.e. happy) facial expressions in dot-probe tasks (Joormann, Talbot, & Gotlib, 2007).

Research in externalising parental psychopathology on the other hand is limited. There is evidence that parental ADHD symptoms were negatively related to children's recognition accuracy of facial emotional expressions (Norvilitis et al., 2000). Adults with externalising symptoms often have difficulty in regulating anger and refraining from angry outbursts (Wender, 1995). Exposure to high levels of maternal anger was generally associated with lower emotional knowledge in preschoolers (Denham, Zoller, & Couchoud, 1994; Dunn & Brown, 1994; Halberstadt, Crisp, & Eaton, 1999). Abused children exhibited preference for vocal than facial cues when their mother compared to a stranger expressed anger (Shackman & Pollak, 2005) and attended more to task-irrelevant angry voices (Shackman, Shackman, & Pollak, 2007) compared to typical children.

Therefore, it is important to explore whether parental externalising psychopathology would have a negative impact on children's emotion processing.

Finally, no studies have examined the relationship between parenting self-esteem, often compromised in parents with psychopathology (Dix & Meunier, 2009), and children's emotion processing. Parenting self-esteem has been suggested to consist of two basic dimensions, namely parenting satisfaction (e.g. levels of frustration or motivation in the parenting role) and perceived self-efficacy (e.g. feeling capable of problem solving) (Johnston & Mash, 1989). Research has shown that parenting sense of competence can play an important role in parenting behaviour (Johnston & Mash, 1989; Rogers & Matthews, 2004). Parenting satisfaction has been associated with positive developmental outcomes and was adversely related to children's externalising and internalising behaviour problems (Hagekull, Bohlin, & Hammarberg, 2001; Hassall, Rose, & McDonald, 2005; Ohan, Leung, & Johnston, 2000). Therefore, it is interesting to explore whether sense of competence in parenting would have a positive impact on children's emotion recognition accuracy.

In summary, adverse early emotional experiences, such as abuse, may negatively influence the development of emotion processing, which may place children in a high risk trajectory for psychopathology (Cicchetti & Curtis, 2005). On the other hand, satisfaction from the parenting role may have a positive influence on children's emotion processing. Future studies in emotion processing should consider socially-mediated mechanisms, such as parent characteristics, and their role in children's emotion processing.

Chapter 3. Study 1- An Exploratory Investigation into Facial and Vocal Emotion Processing in Preschoolers with Behaviour Problems.

3.1 Introduction

The present study builds upon previous work on emotion processing in children with externalising and internalising symptoms to address the important question of which aspects of emotion processing are associated with different dimensions of problem behaviour in children such as hyperactivity, conduct problems and internalising symptoms. The present study takes previous research forward in a number of ways:

First, based upon previous work underlying the preschool period as a sensitive period in the development of emotional competence and social skills (Denham et al., 2003; Izard et al., 2001; Philippot & Feldman, 1990; Saarni, 1999; Wellman et al., 2001) the present study will focus specifically on children of this age group. The preschool years constitute a landmark for the development of emotion understanding as emotional knowledge during the preschool years can have long-term implications for children's social competence (Denham et al., 2003). Research with preschoolers can enhance understanding of the foundations of children's socio-emotional competence and encourage future efforts for targeted intervention with younger children (Izard, Fine, Mostow, Trentacosta, & Campbell, 2002; Izard et al., 2008). Thus far, studies on facial and vocal emotion recognition in children with behaviour problems have focused on school-aged children (Manassis et al., 2007; Pelc et al., 2006). Some preliminary evidence suggests that emotion recognition difficulties in children with behaviour problems may have their origins in the preschool years (Martin et al., 2010). The present study extends current knowledge to the preschool period to carefully examine the developmental origins of previously reported difficulties.

Second, the majority of studies so far have focused on facial emotion recognition (Boyatzis et al., 1993; Bullock & Russell, 1984; Durand et al., 2007; Widen & Russell, 2003). Limited studies exist on young children's vocal emotion recognition (Stifter & Fox, 1986; Verbeek, 1996). The present study aims at incorporating vocal emotion as well as facial in measures of emotion recognition. Focusing on vocal as well as facial expressions is of importance for a number of reasons. The study of vocal, as well as facial, emotional expressions provides a more ecologically valid measure of children's non-verbal social communication patterns. Children have been shown to prioritise vocal, compared to facial, emotional signals of familiar adults (Shackman & Pollak, 2005) and use such signals to regulate their behaviour (Mumme et al., 1996). Vocal emotional expressions can be particularly useful in capturing children's attention in parent-child interactions (Fernald, 1993). Therefore, vocal expressions serve important adaptive funtions in typical development. In addition, individual differences in the ability to identify emotion in other children's (Rothman & Nowicki, 2004) and adults' (Baum & Nowicki, 1998) tone of voice has consistently been linked to preschoolers' social competence including socio-metric status (Nowicki & Mitchell, 1998), observations in free-play activities (Verbeek, 1996), teacher-rated social competence (Goonan, 1995) and security of relationships with parents (Houtmeyers, 2000). In school-aged children, sensitivity to vocal emotion has been linked to teacher ratings of peer relationships (Maxim & Nowicki, 1997). Research with school-aged children has shown that it was the vocal, but not the facial, emotion misrecognition that was associated with externalising symptoms (Norvilitis et al., 2000; Shapiro et al., 1993). In summary, sensitivity to vocal emotion is a fundamental element to children's social adjustment.

In order to identify subtle patterns of vocal emotion recognition in preschool children, this study will utilise different levels of intensity of vocal (as well as facial) emotions. Previous research has shown that it was the perception of the low (but not high) intensity of the vocal stimuli that was associated with social competence in preschoolers (Verbeek, 1996). Different intensity levels reflect different levels of difficulty in emotion recognition and can capture subtleties in children's emotion recognition patterns (Pelc et al., 2006). Variation in intensity can thus provide a more robust measure of sensitivity to emotion (review by Scherer, 2003). In addition, recognition of emotion from ambiguous (low intensity) vocal cues would facilitate the study of misattribution patterns, which in comparison to accuracy, are considered to play a central role in children's social adjustment (Barth & Bastiani, 1997; Schultz et al., 2004)

Third, based on evidence showing emotion recognition difficulties in children with hyperactivity (Corbett & Glidden, 2000; Kats-Gold et al., 2007; Norvilitis et al., 2000; Pelc et al., 2006; Singh et al., 1998), conduct problems (Cadesky et al., 2000; Dadds et al., 2006; Herpertz et al., 2005) and internalising symptoms (Manassis, 2000; Richards et al., 2007), the present study aims to understand whether aspects of children's emotion recognition processes are linked differentially and independently to specific behavioural manifestations of externalising problems such as conduct problems and hyperactivity, as well as internalising symptoms in preschoolers. Existing studies have provided contradictory evidence with respect to the presence of emotion recognition deficits in children with hyperactivity (Boakes et al., 2008; Egan et al., 1998) and conduct problems (Ellis et al., 1997; Guyer et al., 2007). It is not clear from the existing literature whether such deficits are driven by conduct problems or generalise to the whole externalising spectrum.

In relation to the above question, it has been suggested that deficits (low sensitivity) are present in school-aged children with hyperactivity whereas biases (misinterpretations of emotions) are more common in children with conduct problems (Cadesky et al., 2000). Recent research has provided preliminary evidence that preschoolers with a range of externalising symptoms presented lower accuracy to perceive sadness from puppet stories but no biases to emotional (i.e. angry) expressions (Martin et al., 2010). These findings have not been replicated with facial and vocal emotion identification tasks in preschoolers with different types of problem behaviour such as hyperactivity, conduct problems and emotional problems. The present study aims to closely examine the specificity of the different sub-domains of externalising symptoms (hyperactivity, conduct problems) to preschoolers' emotion processing style (deficits, biases).

Fourth, to date, only a few studies have examined the effect of both externalising and internalising symptoms in preschool children on facial and vocal tasks to assess the specificity of emotion processing deficits and biases to externalising and internalising psychopathological conditions. Current research supports a more impaired pattern of processing in children with comorbid internalising and externalising symptoms compared to either condition alone (Manassis et al., 2007). Research in school-aged children has consistently linked externalising symptoms to anger processing biases (Dodge, Bates, et al., 1990; Ellis et al., 1997; Schultz et al., 2000; Schultz et al., 2004) and deficits (Leist & Dadds, 2009; Pelc et al., 2006). Internalising symptoms have been associated with biases to threatening (i.e. angry) emotional stimuli (Bar-Haim et al., 2007) including faces (Perez-Olivas et al., 2008) and sadness processing biases (Ellis et al., 1997). The present study aims to disentangle internalising and externalising aspects of problem child behaviour and separately examine the precise emotion processing mechanisms underlying each condition.

Fifth, grounded on theoretical and empirical accounts of the contribution of child and parent characteristics in children's emotion recognition abilities (review by Gross & Ballif, 1991; Norvilitis et al., 2000), this study will explore separately the influence of parental factors on children's emotion processing. Following models of developmental psychopathology (Cicchetti & Rogosch, 2002), the present study aims to explore the origins of social information processing difficulties in child psychopathology in a parenting context (Hadwin et al., 2006). For instance, depressed mothers displayed more sadness and less positive affect compared to non-depressed mothers (Field, Healy, Goldstein, & Guthertz, 1990; Weinberg & Tronick, 1998). Children exposed to maternal depression presented less effective strategies of emotion regulation (Silk, Shaw, Skuban, Oland, & Kovacs, 2006), scored lower on measures of emotional knowledge (Greig & Howe, 2001) and displayed a number of deficits (Diego et al., 2002) and biases (Field et al., 1998) in processing facial emotional expressions. Limited research has explored vocal emotion processing in relation to maternal depression, especially during the preschool years. Based on current literature, the present study predicted that maternal depression would be associated with preschoolers' lower recognition accuracy for facial and vocal emotional expressions.

Similarly, limited research has examined direct links between externalising maternal psychopathology and children's emotion recognition from faces and voices. There is some preliminary evidence that parents with ADHD symptoms had children who were less accurate in recognising facial expressions of emotion (Norvilitis et al., 2000). In addition, anger biases have been linked to emotion socialisation processes wihin the family (Frick & Morris, 2004). High levels of hostility and anger often characterise parents with symptoms of ADHD (Ramirez et al., 1997). Hostile maternal appraisals of social situations have been linked to increased anger biases in children (Root & Jenkins, 2005). Children exposed to elevated levels of maternal anger attended more to angry faces (Cicchetti & Curtis, 2005) and voices (Shackman et al., 2007) and allocated more cognitive resources toward processing vocal anger (Shackman et al., 2010). Preschoolers also exhibited dysregulated emotion patterns under condition of simulated parental anger (Maughan & Cicchetti, 2002). The present study, therefore, predicted lower accuracy and higher biases to anger in children of parents with externalising symptoms. Research in this direction is important and holds promise for future studies intervening early to promote healthy non-verbal communication patterns in parent-child dyads.

3.2 Aims

The aims of the present study were as follows:

1. To examine whether associations between emotion processing and externalising symptoms found in school-aged children are already present in the preschool years.

2. To examine whether possible emotion processing deficits and biases are modality specific (i.e. facial/vocal).

3. To examine the specificity of the different sub-domains of externalising symptoms (i.e. hyperactivity, conduct problems) to different emotion processing difficulties.

4. To examine these effects in relation to internalising symptoms such as emotional problems and temperamental dispositions of shyness and emotionality.

5. To explore associations between children's emotion processing and parent characteristics.

3.3 Methods

3.3.1 Participants

A total of 57 children from the community (mean age = 4 years 5 months, SD =0.89 years, range = 2 years; 6 months to 6 years; 3 months, 33 boys, 24 girls) with English as their first language participated in this study along with their birthmothers. The mothers' ages ranged from 20 to 43 years (M= 32.86, SD=5.68). Of the 65 children initially approached, 41 were recruited via nursery schools. A further sixteen children, out of 32 initially approached, were recruited from local clinical services, where they had been referred by doctors and health visitors as being at high risk for clinical hyperactivity. Teachers and clinicians were asked to recommend for the study children with no sight, hearing and speech or language problems as assessed via school and clinical records.

3.3.2 Sampling Strategy

The sampling strategy employed in this study and throughout the present thesis aimed to identify the full range of clinical representation of children's psychopathological characteristics from no symptoms through to symptoms. Children who participated in this research were mainly children from the general population who displayed a range of different levels of hyperactivity as well as symptoms of oppositionality and internalising symptoms. Although a small number of children were recruited from clinical services, this served the representation in the sample of some extreme cases of symptoms, not often encountered in the population, but by no means represented cases or diagnoses of ADHD or other disorder. This sampling strategy was chosen because it was judged more powerful for the purposes of the present thesis. The use of continuous rather than categorical measures of children's psychopathological traits was compatible with a correlational rather than a case-control approach to child symptomatology.

3.3.3 Materials

3.3.3.1 Facial Expression Stimuli

A set of 3 (emotions: happiness, anger and sadness) x 2 (intensity levels: 50% and 75%) expressions of the same female model constituted the facial expressions stimulus material in the present study. The study employed facial expressions of a moderate (50%) and high (75%) intensity level per emotion type and a neutral (i.e. 0% emotion) expression. Each facial expression was displayed to the child across the above levels leading to 6 different emotion x intensity conditions plus 1 neutral condition. The material used for the assessment of facial recognition consisted of standardized pictures of emotional facial expressions (Ekman & Friesen, 1976, see revised version by Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002).

3.3.3.2 Vocal Expression Stimuli

3.3.3.2.1 Vocal stimuli battery

An integral part of the present study was to develop appropriate stimuli for inclusion in the experimental task given the lack of appropriate English accent stimuli in the literature. Vocal expressions for the present study were based on a battery of American accent vocal stimuli (Diagnostic Analysis of Non-Verbal Accuracy-DANVA-II) with high levels of construct validity and internal consistency in preschoolers (coefficient alphas=.71) (Verbeek, 1996). DANVA consists of standardised vocal expressions of anger, happiness and sadness at moderate and high intensity levels. For the purposes of the present study, adult vocal emotional expressions from the Adult Paralanguage subtest (DANVA-II-AP; Baum & Nowicki, 1998) were adapted in order to render the stimuli appropriate for use with English speaking children. This involved developing vocal stimuli delivered with a standard UK accent.

3.3.3.2.2 Vocal stimuli development

At a first stage, vocal expressions consisting of the sentence *'I will go out of the room now, but I'll be back later'* were recorded with Cool Edit, 1.2, with the help of an English native speaker female actress. The actress was asked to produce expressions to approximate a moderate-50% and a high-75% intensity level per emotion category. The English native speaker female actress was asked to produce 6 trials for moderate-50% and 6 trials for high-75% intensity resulting to a total of 12 trials per emotion type (angry, happy, sad) and 10 neutral expressions. A total number of 46 trials to be further validated were judged an adequate pool of recordings for the purposes of the present study. The American DANVA-AP-II used a larger pool of 133 recordings for further validation as this larger number covered two actors and four emotion categories in contrast to this study employing one actor and three emotion categories.

3.3.3.2.3 Vocal stimuli validation

At a second stage, 18 20- to 52-year-old independent judges, English native speakers, (mean age=27.05, SD=8.68, 15 females) listened to each one of the 46 stimuli produced by the actress and rated whether it was '*angry*', '*happy*', '*sad*', or *'neutral/ok'*. After selecting one (emotion) word per vocal item, participants were asked to indicate how intense the emotion they had chosen (i.e. angry) was on a 1-8 scale from *'not at all angry'* to *'extremely angry'*. Inter-rater agreement on how representative each item was of a particular expression was satisfactory with an overall agreement among the judges of 71.56%. The inter-rater agreement (%) on how representative each expression was, item by item, and by emotion x intensity category, is presented in Appendix A.

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3.3.3.2.4 Vocal stimuli selection

At a last stage, means and standard deviations of the judges' intensity ratings formed the basis of the selection of the final vocal expression items to be included in the experimental design. From those vocal stimuli rated by the judges as belonging to the same emotion category (i.e. angry) the study selected the item(s) which reached the highest intensity rating (see Appendix A). Seven stimuli were selected for the final set from the original sample of 46 trials based on the means (SD) of the judges' ratings on the eight point scale: High intensity: Angry: M=6.38, SD=2.00, Happy: M=5.72, SD=1.74, Sad: M=6.33, SD=1.78; Low intensity: Angry: M=4.55, SD=2.82, Happy: M=3.77, SD=2.36, Sad: M=4.11, SD=2.58 and Neutral: M=4.88, SD=2.13. For consistency, and as there were not fully equivalents of the means per emotion, stimuli with as close as possible to two units of difference between high and low intensity per emotion were selected. Overall agreement among the judges on how representative the seven selected items were of each emotion category was as follows: High intensity: Angry: 94.4%, Happy: 100%, Sad: 94.4%; Low intensity: Angry: 88.9%, Happy: 83.3%, Sad: 77.8% and Neutral: 94.4% (see Appendix A). In summary, a set of 2 (intensity levels: 50% and 75%) x 3 (emotions: happiness, anger and sadness) expressions alongside a neutral expression from the same female actress constituted the vocal expressions stimulus material in the present study.

3.3.4 Task Design

Children took part in two tasks i) a facial emotional expression and ii) a vocal emotional expression identification task with tasks counterbalanced in order across participants. The experiment consisted of a four choice emotion identification task with four response options (angry, happy, sad and neutral/'ok') across 2 modalities (i.e. facial/vocal) and intensities (i.e. moderate-50%, high-75%). Each task (face/voice) consisted of 70 experimental trials (10 trials per emotion x intensity condition plus a neutral expression) presented in two blocks of 35 trials each. There was a 5-minute rest break in between the two blocks. Children participated in 7 practice trials identical to those in the experimental trials (one per emotion x intensity condition, plus a neutral) at the beginning of each task. Children were given clear instructions about the response options and did not receive feedback about their performance accuracy. Children took part in the second task (i.e. either face or voice) after completion of the first task. The following instructions were given to the children verbally before the practice block of each task:

'You are going to see some faces/hear some voices. You need to tell me if the face/voice is angry, happy, sad or okay. You need to decide as accurately as possible. In between each face/voice you will see a small cross on the centre of the screen. Please look at this throughout the task. If you don't understand the instructions, ask the experimenter now'

After checking that the children had understood the instructions, children continued on to the practice trials and the main experimental block. Each trial begun with the presentation of a central fixation cross (500 ms) followed by the presentation of the stimulus (3000 ms in the case of facial and vocal expressions) followed by a blank screen until the participants gave a verbal response and a 1000 ms inter-trial interval (ITI). Facial expressions were displayed on a computer monitor. Vocal expressions were presented via speakers. Stimuli were presented in counterbalanced order across participants. Immediately after presentation of the stimulus, the experimenter read-out to the child four response options (is the face/voice angry, happy, sad or okay?). The experimenter read out the emotion words in counterbalanced order across trials. This was facilitated by use of script cards (6 possible combinations of emotion words x 4 emotions leading to a number of 24 script cards). Participants' verbal responses were logged into the computer by the experimenter via Inquisit Software v.2 (Millisecond.com).

3.3.5 Child and Parent Measures of Psychopathology

3.3.5.1 Parent-rated Measures of Child Behaviour

3.3.5.1.1 Strengths and Difficulties Questionnaire (SDQ)

The SDQ parent version (Goodman, 1997) is a 33-item behavioural screening questionnaire with good psychometric properties, ά=0.85, (Goodman, 1997, 2001) for 3- to 4-year-olds. Cronbach's alpha in the present study for the scale as a whole was .79. The first 25 items are rated on a 3-point Likert-type scale (0=not true, 1=somewhat true, 2=certainly true) whereas all other items are rated on a 4 point Likert-type scale (0=not at all, 1=only a little, 2=quite a lot, 3=a great deal). The questionnaire consists of several scales assessing pro-social behaviour (items 1, 4, 9, 17 and 20) and different types of problem behaviour including hyperactivity (items 2, 10, 15, 21 and 25), conduct problems (items 5, 7, 12, 18 and 22), emotional problems (items 3, 8, 13, 16, and 24) and peers problems (items 6, 11, 14, 19 and 23). A total difficulties score can be obtained by summing up the scores of the hyperactivity, conduct, emotional and peers problems scales. Items 7, 11, 14, 21 and 25 are reversed scored. There is a 'some needs' cut-off of 6, 3 and 4 or more out of a total of 10 symptoms for hyperactivity, conduct and emotional symptoms respectively (Goodman, 1997). For the purposes of the present thesis a dimensional approach was adopted with higher scores reflecting higher level of symptoms.

3.3.5.1.2 Werry Weiss Peters activity questionnaire (WWP)

The WWP (Routh, 1978) was also used to gain further information regarding hyperactive symptoms in children. The WWP is a well validated 27-item questionnaire assessing child hyperactivity. Exemplar questions include: 'When drawing, colouring, writing or doing homework, does the child get up and down'. All items are rated by the parent on a 3- point Likert type scale (0=no or hardly ever, 1=yes, fairly often, 2=yes, very often). The psychometric properties of WWP are reported to be satisfactory (Routh, 1978). A global score is created corresponding to a total hyperactivity level by adding up all item scores. There is a cut-off point of 20 or more symptoms (Routh, 1978); however, in the present study a dimensional approach was adopted with higher scores reflecting higher activity levels. Cronbach's alpha in this study for the scale was .95.

3.3.5.1.3 Emotion Regulation Checklist (ERC)

The ERC (Shields & Cicchetti, 1997) is a 24-item questionnaire designed to tap into two dimensions of children's emotion self-regulatory abilities: emotion dysregulation (i.e. lack of flexibility, mood lability and dysregulated negative affect) and emotion regulation, (i.e. situationally appropriate affective displays, empathy and emotion self-awareness). Responses are rated on a 4-point Likert scale (1=never, 2=sometimes, 3=often, 4=always). There are two sub-scales corresponding to the above two dimensions: First, emotion dysregulation (items 2, 6, 8, 10, 13, 14, 17, 19, 20, 22, and 24 (positively scored) and items 4, 5, 9, and 11 (reverse scored). Second, emotion regulation (items 1, 3, 7, 15, 21 and 23 (positively scored) and items 16 and 18 (reversed scored). The above items generate a total (0-32) score for the emotion regulation and a separate (0-60) score for the emotion dysregulation sub-scale. Exemplar questions of the emotion dysregulation scale include 'child is prone to angry outbursts' and 'child responds negatively to neutral or friendly approaches by peers'. There are no cut-off points; higher scores reflect higher emotion regulation or dysregulation. The ERC has been designed for school-aged children; however, it can produce valid results with younger ages (Cicchetti, personal communication, Dec 2006). Internal consistency of the ERC is good with Cronbach's alphas of .96 for the emotion dysregulation subscale, .83 for the emotion regulation subscale and .89 for the scale as a whole (Shields & Cicchetti, 1997). Cronbach's alpha in the present study for the scale as a whole was .73.

3.3.5.1.4 Temperament Questionnaire

This is a 10-item questionnaire assessing shyness and emotionality in preschoolers (Buss & Plomin, 1984). Exemplar questions include 'child tends to be shy' and 'child tends to be somewhat emotional'. Each item is rated on a 5-point Likert scale from 'not typical' to 'very typical'. The questionnaire consists of two scales: Shyness (items 1-5) and emotionality (items 5-10). Items 2, 3 and 5 are reversed scored. Scores are summed to produce an overall (0-25) score for each sub-scale with higher scores reflecting higher levels of shyness and emotionality (Buss & Plomin, 1984). There is no cut-off point; higher scores reflect higher levels of shyness and emotionality. Test-retest correlations have been found to be .72 for the emotionality scale and .58 for the shyness scale (Buss & Plomin, 1984). Cronbach's alpha in the present study for the scale as a whole was .70.

3.3.5.2 Self-report Measures of Parent Characteristics

3.3.5.2.1 Attention Deficit Hyperactivity Disorder-Current Behaviour Scale

The ADHD-CBS is a self-report scale (Barkley & Murphy, 1998) consisting of 18 items derived from the 18 ADHD symptom criteria for adults reported in the DSM-IV. Each of the 18 items is rated on a 4-point Likert scale (never, sometimes, often, very often). For the purposes of the present study, frequency of reported symptoms was measured (never, sometimes, often=0, very often=1). The scale contains two factors, inattention and hyperactivity/impulsivity. The first item refers to inattention (e.g. 'fail to give close attention to details') and items corresponding to each of the above two factors alternate with each other. Inattentive and hyperactive/impulsive adults are those who score in the top 20th percentile on the ADHD rating scale's inattentive and hyperactive factor respectively, that is, adults who report six or more symptoms as occurring 'sometimes' 'often' or 'very often' in items corresponding to each factor. Finally, ADHD 'combined type' describes individuals who report 12 or more symptoms additively on the two factors (inattentive and hyperactive/impulsive). In the present study no cut-off points were used. Factor analytic studies have shown high internal consistency and good construct validity for factors corresponding to inattentive and hyperactive /impulsive symptoms (Collett, Ohan, & Myers, 2003). The Cronbach's alpha in the present study was .93.

3.3.5.2.2 General Health Questionnaire (GHQ)

The present questionnaire (Goldberg, 1978) is a self-report measure designed to assess depressive symptoms in adults. It consists of 12 items (short version) rated on a 4-point Likert scale (more so than usual, same as usual, less so than usual, much less than usual). Levels on the 4-point scale are counterbalanced in order and indicate frequency with which symptoms occur. The first two levels on the scale are scored as 0 and the next two levels as 1. Exemplar items include 'I felt capable about making decisions about things or 'I lost much sleep over worry'. This questionnaire is unidimensional and therefore a single global score is calculated by summing the scores of all items. A cut-off point ≥ 2 is recommended for depression (Goldberg, 1972, 1978). In recent studies using this cut-off point, 23% of adults in the general population fell in the atypical range for depression (Hoeymans, Garssen, Westert, & Verhaak, 2004). In the present thesis, higher scores indicated higher levels of depressive symptoms and no cut-off points were used (Goldberg, 1978). Research on the GHQ reports high rates of internal consistency with Cronbach's alpha ranging from .82 to .93 (Goldberg & Williams, 1998; Goldberg, 1978). The Cronbach's alpha in the present study was .85.

3.3.5.2.3 Parenting Sense of Competence (PSOC)

This is a 17-item questionnaire assessing attitudes and feelings which relate to parenting with 4- to 9-year-old children (Johnston & Mash, 1989). In this study, items were rated on a 5-point Likert scale (1=strongly agree, 2=agree, 3=unsure, 4=disagree, 5=strongly disagree). The questionnaire consists of two sub-scales. The satisfaction sub-scale (items 2, 3, 4, 5, 8, 9, 12, 14 and 16) assesses the general level of satisfaction from parenting. The second, self-efficacy sub-scale (items 1, 6, 7, 10, 11, 13, and 15) assesses perceived self-efficacy of the parent in the parenting role (i.e. expectations for successful coping). Scores are summed up in each subscale to create a 'satisfaction' and 'self-efficacy' general score. An overall competence score is obtained by summing up the scores of the two subscales. There is not a cut off point for each subscale. Higher scores reflect higher levels of satisfaction and perceived self-efficacy. Internal consistency of the PSOC is good with Cronbach's alphas of .75 for the satisfaction scale, .76 for the self-efficacy scale and .79 for the scale as a whole (Johnston & Mash, 1989). PSOC has been found to be significantly negatively correlated with child problem behaviour (Johnston & Mash, 1989). The Cronbach's alpha in this study for the whole scale was .83.

3.3.6 Procedure

Research protocols and stimuli were granted ethical approval from the School of Psychology and the NHS Central Office for Research Ethics, Committee A'. Participants were approached through local clinical services and nursery schools which agreed to forward a letter of information and consent to parents and children. Parents who expressed interest in the study via the nurse therapist or Head teacher were contacted by the researcher to arrange a home visit to take part in the study. Parents gave informed written consent and children written assent for participation. During the home visit, questionnaire measures were completed by the parents whilst the child and the researcher completed the emotion identification task in a separate room. A small number of participants completed the above procedure in a quiet room of the clinic. Participants received a summary of the study's results after completion of the study.

3.4 Data Processing

3.4.1 Discrimination Accuracy

In the present study and throughout the thesis, raw data were transformed into measures of discrimination accuracy (Pr) following the two high threshold (2HT) model (Corwin, 1994) used in studies examining emotion recognition accuracy and response bias in psychiatric populations (Surguladze et al., 2004). Discrimination accuracy is defined as sensitivity to discriminate an emotional expression and is given by the following equation: Pr = ((number of hits + 0.5) / (number of targets + 1)) – ((number of false alarms + 0.5) / (number of distractors + 1)) (Corwin, 1994). In other words, the number of non-target expressions identified as a target (false alarms) + 0.5 divided by the total number of non-target expressions +1 (distractors) was subtracted from the number of hits (i.e. number of correct responses) + 0.5 divided by the number of target expressions +1. Performance at better than chance levels would yield positive values which tend to 1. Performance approaching chance levels would yield values which tend to zero (0). Finally, performance at worse than chance levels would yield negative values which tend to -1. Note that transformations are added in the above formulae (i.e. + 0.5) to prevent divisions by zero.

Formulae with multiple distractors were used to take into account all possible emotion x intensity conditions as distractors, in three separate subsets of target expressions (angry, happy and sad). For example, in a task with 10 trials of each of the 7 conditions: angry, happy and sad at two intensity levels per condition (i.e. 50% and 75%) plus one neutral condition, accuracy to identify angry faces of 50% intensity would be as follows: ((number of angry 50% faces classified as angry + 0.5) / (10+1))-((number of neutral faces classified as angry + number of happy 50% faces classiffied as angry + number of happy 75% faces classified as angry + number of sad 50% faces classified as angry + number of sad 75% faces classiffied as angry+0.5)/(50+1)). For example, if a child classified 9 angry 50% faces as angry but he/she also classified as angry 7 neutral faces, 4 happy 50% faces, 3 happy 75% faces, 4 sad 50% faces and 5 sad 75% faces, then his/her accuracy would be: ((9 + 0.5) / (10+1)) – ((7+4+3+4+5+ 0.5) / (50+1)) = 0.40, suggesting that recognition accuracy is better than chance.[1]

[1] Similarly, if a child classified 0 angry 50% faces as angry and also classified as angry 8 neutral faces, 6 happy 50% faces, 5 happy 75% faces, 8 sad 50% faces and 7 sad 75% faces, then accuracy would be: (0 + 0.5)/ (10+1) – ((8+6+5+8+7+ 0.5) / (50+1)) = - 0.63, suggesting that recognition accuracy is below chance. Finally, if a child classified 10 angry 50% faces as angry and also classified as angry 10 neutral faces, 10 happy 50% faces, 10 happy 75% faces, 10 sad 50% faces and 10 sad 75% faces, then accuracy would be: (10 + 0.5)/ (10+1) – ((10+10+10+10+10+ 0.5) / (50+1)) = - 0.03, suggesting that accuracy is near chance (zero).

3.4.2 Response Bias

In the present thesis response bias (Br) was computed according to false alarm scores, defined as the tendency to attribute a particular emotion to an expression when uncertain about the category to which the expression belongs and is given by the following equation: Br= ((number of false alarms + 0.5) / (number of distractors + 1)) / (1-Pr) (Corwin, 1994). Values that tend to 1 indicate the presence of a systematic bias whereas values that tend to zero (0) indicate the absence of a systematic bias toward a particular expression. Response bias was computed with reference to measures of false alarms including both neutral and emotional expressions. Formulae with multiple distractors were used to take into account all possible emotion conditions as distractors, in three separate subsets of targets (angry, happy and sad). Because the present thesis used the confusability matrices for a comprehensive analysis of bias scores of different intensities, intensity was not included as a factor in the bias formula above. The bias formula was therefore adjusted to incorporate accuracy (Pr) scores with 'combined' intensity levels per emotion.

For instance, in the same example of experimental design given above (10 face trials per emotion), response bias to angry face would be as follows: ((number of neutral faces classified as angry + number of total happy faces classified as angry + number of total sad faces classified as angry + 0.5) / (50 +1)) / (1- accuracy (Pr) for angry face). For example, if a child had an accuracy score (Pr) of 0.50 for angry faces (combined accuracy (Pr) scores of angry 50% and 75%) and also classified as angry 8 neutral, 6 happy and 8 sad faces, then his/her response bias score would be as follows: ((8+6+8+0.5)/ (50+1)) / (1-0.50) =0.88, suggesting an elevated bias toward angry faces. However, if a child had an accuracy score (Pr) of 0.50 for angry faces and he/she also classified as angry 2 neutral, 0 happy and 3 sad faces, then his/her response bias score would be as follows: ((2+0+3+0.5)/ (50+1))/(1-0.50) =0.21, suggesting low bias toward angry faces.

3.5 Results

3.5.1 Performance

3.5.1.1 Initial Data Treatment-Accuracy and Bias

Kolmogorov-Smirnov tests were conducted for the accuracy and bias measures for facial and vocal expressions. Values of discrimination accuracy for facial and vocal expressions did not differ significantly from normality ($p > .05$) except for happy 75% ($z=1.42$, $p=.035$) and angry 75% ($z=1.66$, $p=.008$) facial expressions and angry 75% vocal expressions ($z= 2.07$, $p<.001$). Because the majority of accuracy measures did not differ significantly from normality, values of accuracy were not transformed. Values of response bias to facial and vocal expressions did not differ significantly from normality ($p > .05$).

3.5.1.2 Discrimination Accuracy

3.5.1.2.1 Overall performance

Initial analyses tested whether children in the overall sample performed above chance levels as for discrimination accuracy. One sample t-tests were conducted for each cell against chance (a score of zero) with values of discrimination accuracy entered in analyses. Results indicated that performance was significantly different from chance for both facial and vocal expressions for all intensity and emotion types [$t(56) > 6.11$, all p values $<.001$].

3.5.1.2.2 Associations between child age and gender and accuracy

In order to examine the effect of child age and gender on accuracy, an aggregated score of accuracy was created by combining the intensity x emotion conditions for facial and vocal expressions. Independent samples t-tests showed no significant difference in accuracy between males and females for facial [$t(55) =-.27$, $p=.79$] and vocal [$t(55) =.01$, $p=.98$] expressions. Also, there was no significant difference between males and females in accuracy at each emotion x intensity condition (ps $>.05$). Pearson's correlations showed that child age was highly associated with accuracy for facial ($r=.34$, $p=.008$) and vocal ($r=.41$, $p=.001$) expressions. Child age was positively associated with accuracy for angry ($r=30$, $p=.020$), happy ($r=.50$, $p<.001$) but not sad ($r=10$, $p=.43$) faces as well as angry ($r=.41$, $p=.002$), sad ($r=.45$, $p<.001$) but not happy ($r=13$, $p=.30$) voices across intensities. For this reason, subsequent analyses with accuracy controlled for child age.

3.5.1.2.3 The effect of emotion, modality and intensity on accuracy

The effect of emotion type, emotion modality and emotion intensity on discrimination accuracy was examined. Accuracy scores were entered in a repeated measures Analysis Of Variance (ANOVA) with 3 emotion (Angry, Happy and Sad) x 2 intensity (Moderate-50%, High-75%) x 2 modality (Face, Voice) as with within-subject factors and values of discrimination accuracy (Pr) as the dependent measure. Child age was entered as a covariate in the model because of the strong association with accuracy.

Results showed a significant difference in accuracy between the two modalities (F (1, 55) =9.23, p=.004, η^2_p =.14). Children were significantly more accurate to discriminate facial than vocal (M=.64, SE=.02, M=.42, SE=.03, p<.001) expressions. Results also yielded a significant modality x emotion interaction effect on accuracy (F (2,110) = 5.65, p=.007, η^2_p =.09), but no significant modality x intensity (F (1, 55) = 1.55, p=.21, η^2_p =.02), emotion x intensity (F (2,110) = .73, p=.48, η^2_p =.01) or modality x emotion x intensity, (F (2,110) =.85, p=0.43, η^2_p =.01) interaction effect on accuracy. There was no significant intensity effect on accuracy (F (1, 55) = 2.93, p=.09, η^2_p =.05).

Further post-hoc analyses on the modality x emotion interaction effect were conducted (see Figure 3.1). For each modality x emotion condition the two intensities were averaged and subsequently entered in two one-way ANOVAs examining the effect of emotion on accuracy for the two modalities separately. Results revealed a significant main effect of emotion on accuracy for facial (F (2,112) =26.61, p<.001) and vocal (F (2,112) =52.20, p<.001) expressions. Pair-wise comparisons showed that children were more accurate to recognise angry than sad and also happy than sad faces (p<.001) but there was no significant difference in accuracy between angry and happy faces (p=1.00). In the voice task, children were more accurate to recognise angry than happy, angry than sad, and sad than happy voices (all ps <.001). Even after covarying for child age, the above results remained significant. Separate paired sample t-tests were conducted for each emotion to examine the effect of modality on accuracy. There was a significant difference in accuracy between the two modalities for angry [t (56) = 3.82, p<.001, M=.10, SD=.20], happy [t (56) = 14.48, p<.001, M =.49, SD= .25] and sad [t (56) = 2.08, p=.042, M=.07, SD=.28] expressions. Table 3.1 presents the mean and standard deviations for discrimination accuracy across emotion type, intensity and modality

Table 3. 1. *Means (SD) of discrimination accuracy across modality, intensity and emotion in the whole sample (N=57).*

	Angry		Happy		Sad	
Accuracy	50%	75%	50%	75%	50%	75%
Face	.64(.28)	.74(.26)	.67(.24)	.75(.20)	.47(.27)	.57(.26)
Voice	.52(.34)	.65(.35)	.16(.20)	.28(.29)	.41(.34)	.47(.32)

Note 1: Accuracy values: -1≈ worse than chance, 0≈ near chance, 1≈ better than chance.
Note 2: t (56) > 6.11, ps<.001 for all emotion x intensity conditions.

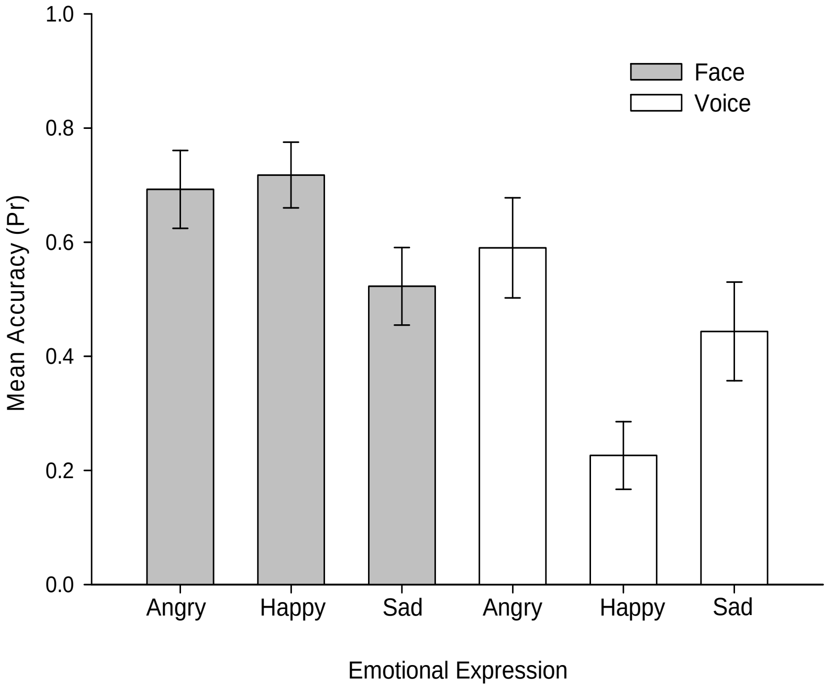

Figure 3. 1. 95% confidence interval bar charts with error bars for mean accuracy (Pr) scores for faces and voices per emotion.

3.5.1.2.4 Data reduction -accuracy

Pearson's correlations showed high inter-correlations between the two intensity levels of accuracy for facial (Pearson's r in the range of .76 to.79, p<.001) and vocal (Pearson's r in the range of .61 to.86, p<.001) expressions. In addition, running the analyses for both intensities separately did not make any difference to subsequent analyses. For this reason, the two intensities were combined for each emotion and modality (face, voice) and entered in subsequent analyses to examine associations with child behaviour.

3.5.1.3 Response Bias

3.5.1.3.1 Associations between child age and gender and response bias

In order to examine the effect of child age and gender on bias, an aggregated score of bias for facial and vocal expressions was created by combining the emotion conditions. Independent samples t-tests examined whether response bias differed for males and females. Results showed no significant differences between males and females in response bias to facial [t (55) =1.14, p=.25] and vocal [t (55) =.19, p=.84] expressions. In addition, there was no significant difference between males and females in response bias for each emotion x modality condition (p >.05). Child age was not associated with response bias to emotional facial or vocal expressions (p>.05). Also, there was no significant association between child age and any emotion x modality condition (p >.05). Therefore, subsequent analyses with response bias did not control for child age.

3.5.1.3.2 The effect of emotion and modality on response bias

The effect of emotion type and emotion modality on response bias was examined. Response bias scores were entered in a repeated measures ANOVA with 3 emotion (Angry, Happy and Sad) x 2 modality (Face, Voice) ANOVA as within-subject factors and values of response bias (Br) as the dependent measure. Child age and gender were not entered as a covariate in the model because they were not associated with bias.

Results showed a significant main effect of emotion on response bias (F (2, 112) =7.41, p=.001, η^2_p =.12). Participants showed higher response bias to sad (M=.36, SE=.03) than angry (M=.25, SE=.02) and happy (M=.24, SE=.02), suggesting a higher tendency to attribute sadness to an expression when uncertain. There was a significant difference in response bias between sad and angry (p=.006) as well as sad and happy (p=.012) but not between angry and happy (p=1.00).

Results also showed a significant emotion x modality interaction effect on response bias (F (2, 112) =5.68, p=.004, η^2_p =.09). Further post-hoc analyses on the modality x emotion interaction effect were conducted (see Figure 3.2). For each modality x emotion condition the two intensities were averaged and then by a one-way ANOVA the effect of emotion on accuracy for the two modalities separately was examined. Results showed a significant difference in bias between emotions for facial (F (2,112) =6.44, p=.004, η^2_p = .10) and vocal (F (2,112) =7.17, p=.001, η^2_p =.11) expressions. Pair-wise comparisons indicated that in the face task, children showed significantly higher bias to sad than angry (p=.003) and happy than angry (p=.039) and but there was no significant difference in bias between happy and sad (p=.461). In the voice task, children displayed significantly higher bias to sad than happy (p=.003) but no other differences reached significance (p>.15). Separate paired sample t-tests were conducted for each emotion to examine the effect of modality on response bias. There was a significant difference in bias between modalities for angry [t (56) = -3.19, p=.002] and happy [t (56) = 2.14, p=.036] but not sad [t (56) = -1.15, p=.252]. It is interesting to note the different direction of effects for bias to angry compared to happy. Bias to anger was higher for vocal than facial expressions while bias to happy was higher for facial than vocal expressions. Table 3.2 presents the means and standard deviations for response bias across emotion type and modality.

Table 3. 2. *Means (SD) of response bias across modality and emotion in the whole sample*

		Angry	Happy	Sad
Bias	Face	.19(.15)	.27(.20)	.34(.27)
	Voice	.29(.21)	.20(.20)	.38(.27)

Note: Response bias values range from 0 -1. Presence of bias ≈ 1, Absence of bias ≈ 0.

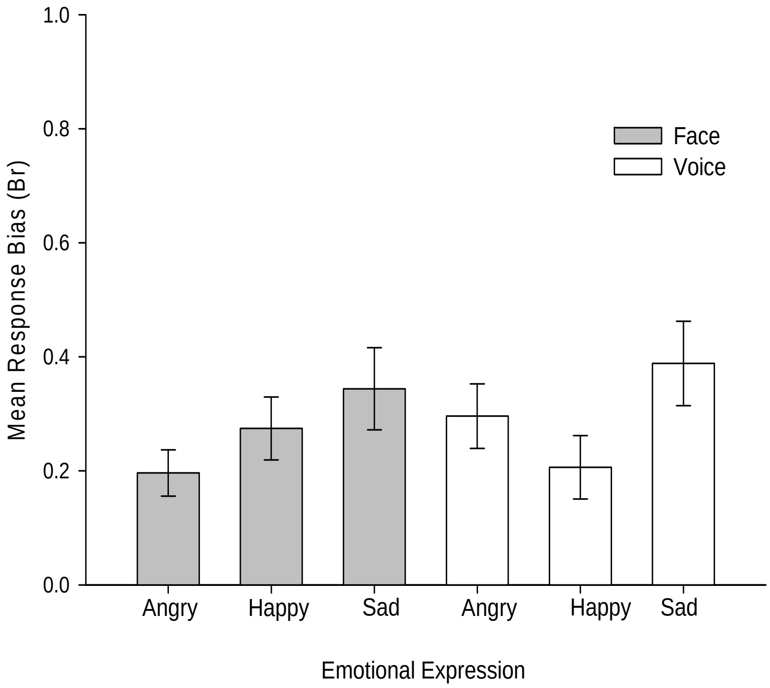

Figure 3. 2. 95% confidence interval bar charts with error bars for mean response bias (Br) scores for faces and voices per emotion

3.5.1.3.3 Correct classifications and misattribution patterns

Alongside the bias analyses, the study examined correct classifications and misattribution patterns (i.e. tendency to confuse one expression with another). In the face task, children classified correctly angry, happy and sad expressions but they tended to classify neutral facial expressions as sad. In the voice task, children classified angry and sad expressions correctly but they tended to confuse more often happy and neutral expressions. Children tended to classify happy voices of moderate intensity as sad and neutral. They also tended to classify neutral voices as sad. Confusion matrices showing which emotion labels were selected if the target emotion was misidentified are presented in Table 3.3.

Table 3. 3. *Mean percentage (SD) of correct recognition (in bold) for facial and vocal expressions per emotion and misclassifications (N=57).*

	Child Response			
Expression	Angry	Happy	Sad	Neutral/ok
Face				
Angry50%	**71.40(28.87)**	5.08(9.08)	11.40(15.40)	7.19(12.50)
Angry75%	**82.28(26.79)**	2.63(5.18)	8.24(18.43)	1.57(5.27)
Happy50%	3.33(6.63)	**78.94(23.65)**	6.49(12.88)	5.43(10.86)
Happy75%	2.98(8.22)	**87.36(19.50)**	3.33(7.63)	3.15(8.05)
Sad50%	6.14(11.14)	7.01(12.67)	**62.28(32.01)**	17.19(26.90)
Sad75%	4.38(8.66)	6.66(10.40)	**73.33(28.61)**	10.87(21.32)
Neutral	4.03(7.75)	16.14(26.96)	36.66(35.11)	**36.84(38.96)**
Voice				
Angry50%	**63.85(33.63)**	12.80(18.29)	9.12(15.61)	11.05(15.19)
Angry75%	**78.94(33.52)**	7.36(16.20)	7.71(14.27)	4.03(7.75)
Happy50%	7.71(13.09)	**29.82(28.12)**	28.59(25.87)	29.64(30.47)
Happy75%	19.47(21.66)	**42.63(32.81)**	13.85(19.61)	21.92(28.93)
Sad50%	5.43(9.27)	14.38(21.79)	**60.17(35.83)**	15.08(19.92)
Sad75%	4.21(9.43)	14.03(23.13)	**67.54(34.44)**	10.52(19.40)
Neutral	11.57(15.78)	22.45(27.46)	28.77(26.25)	**32.45(31.80)**

Note: Missing data were due to non-response.

3.5.1.4 Intercorrelations between accuracy and bias

Additional analyses aimed to examine inter correlations between discrimination accuracy and response bias. Overall accuracy scores for facial and vocal expressions were highly associated ($r=.64$, $p<001$). Response bias scores to facial and vocal expressions were also significantly associated ($r=.34$, $p=.011$). There was also a tendency for accuracy and bias to be intercorelated in the voice task ($r=.24$, $p=.072$) but not the face task ($r=.038$, $p=.77$). Intercorrelations between the emotion processing measures for each emotion and modality separately, were also examined via partial Pearson's correlations controlling for child age. Accuracy for facial and vocal expressions was highly intercorrelated across emotions. Response bias to sad and happy faces and voices were significantly associated with each other but this was not the case for angry expressions. Results are presented in Table 3.4.

Table 3. 4. *Partial Pearson's correlations (p value) between the emotion processing measures controlling for child age*

	Pr Angry Face	Pr Happy Face	Pr Sad Face	Pr Angry Voice	Pr Happy Voice	Pr Sad Voice	Br Angry Face	Br Happy Face	Br Sad Face	Br Angry Voice	Br Happy Voice	Br Voice Sad
Pr Angry Face												
Pr Happy Face	**.62(.001)**											
Pr Sad Face	**.61(.001)**	**.52(.001)**										
Pr Angry Voice	**.76(.001)**	**.48(.001)**	**.46(.001)**									
Pr Happy Voice	**.29(.027)**	**.29(.026)**	.14(.283)	**.59(.001)**								
Pr Sad Voice	**.47(.001)**	**.49(001)**	**.55(.001)**	**.65(.001)**	**.46(.001)**							
Br Angry Face	**-.29(.030)**	-.06(.619)	.15(.262)	.12(.370)	-.11(.398)	.01(.900)						
Br Happy Face	-.10(.430)	-.11(.395)	-.20(.128)	-.17(.211)	-.05(.706)	-.25(.062)	.20(.155)					
Br Sad Face	-.09(.481)	.08(.557)	**.37(.005)**	.06(.654)	.16(.231)	**.38(.004)**	-.12(.379)	-.15(.259)				
Br Angry Voice	**.42(.001)**	.11(.400)	**.29(.003)**	**.30(.021)**	.-.06(.663)	.08(.572)	.18(.171)	-.63(.645)	-.17(.202)			
Br Happy Voice	-.01(.927)	.07(.597)	**-.30(.021)**	-.03(.824)	**.29(.032)**	-.20(.122)	-.12.(.351)	**.35(.009)**	-.03(.787)	**-.29(.028)**		
Br Sad Voice	-.02(.907)	-.09(.517)	.39(.077)	-.10(.441)	.16(.227)	**.35(.008)**	.14(.289)	-.06(.645)	**.44(.001)**	.00(.993)	**-.29(.028)**	-

Note: Pr= Discrimination Accuracy, Br=Response Bias.

3.5.2. Child Psychopathology

3.5.2.1 Sample Characteristics

The present study followed a dimensional approach to child psychopathology. The proportion of children in the atypical range for the key child measures was also explored using the recommended cut-offs (see section 3.3.5). Table 3.5 displays the means and standard deviations of the child measures and the percent of children in the atypical range in the whole sample.

Table 3. 5. *Means (SD) for child measures in the whole sample*

	Mean	SD	% atypical range
SDQ			
Pro-social	7.73	1.92	-
Peers	2.21	1.91	-
Hyperactivity	4.52	3.00	31.6%
Emotional	2.15	2.01	23.3%
Conduct	3.24	2.75	50.9%
WWP			
Hyperactivity	15.10	12.62	29.8%
TS			
Emotionality	13.01	4.18	-
Shyness	14.91	2.87	-
ERC			
Emotion Dysregulation	29.26	7.42	-
Emotion Regulation	25.89	3.71	-

Note: SDQ: Strengths and Difficulties Questionnaire, TS: Temperament Survey, ERC=Emotion Regulation Checklist, WWP: Werry Weiss Peters Activity Scales. No cut-off available for ERC and TS.

3.5.2.2 Data Reduction-Child Psychopathology

Further analyses aimed to reduce the items representing child symptoms to a smaller number of factors to facilitate the interpretation of the findings. This was supported by high inter correlations among a cluster of child symptoms (in the range of Pearson's r=.70-.89, p<.001). Child symptoms including hyperactivity (SDQ and WWP), emotional problems, conduct problems, shyness, emotionality and emotion dysregulation were factor analysed through principal component analysis (PCA) with varimax rotation (eigenvalues greater than 1). The scree plot indicated two factors to be extracted accounting for 73% of the total variance. The eigenvalues for the two factors were 4.1 and 1.0. The first factor consisted of items of hyperactivity (SDQ), hyperactivity (WWP), conduct problems and emotion dysregulation. The second factor consisted of items of emotional symptoms, shyness and emotionality. The two factors were named as 'Externalising' and 'Internalising' respectively because they comprised items characteristic of externalising and internalising child symptom dimensions respectively. The factor pattern matrix is presented in Table 3.6.

Table 3. 6 . *Factor pattern matrix for child behaviour characteristics*

	Externalising	Internalising
Hyperactivity (SDQ)	**.911**	.124
Hyperactivity (WWP)	**.942**	.146
Conduct problems	**.893**	.248
Emotion dysregulation	**.785**	.429
Shyness	-.033	**.756**
Emotionality	.375	**.713**
Emotional problems	.356	**.641**

Note. SDQ: Strengths and Difficulties Questionnaire, WWP: Werry Weiss Peters Activity Scales.

3.5.2.3 Emotion Processing and Child Psychopathology

After determining the factorial structure of child symptoms, subsequent analyses aimed to explore association patterns between child symptoms and emotion processing (discrimination accuracy and response bias). Accuracy analyses controlled for child age because of the strong association between child age and discrimination accuracy.

Results yielded a negative relationship between children's externalising behaviour problems and discrimination accuracy for vocal expressions across all emotion types. In addition, externalising behaviour problems were negatively associated with accuracy for happy faces. No associations emerged between discrimination accuracy and internalising behaviour problems and between response bias and internalising or externalising symptoms. When a Bonferroni correction was applied with an alpha level of .05/12=.004 adopted, only the negative association between externalising problems and accuracy for sad voices remained significant. Results are summarised in Tables 3.7 and 3.8.

The above pattern of findings based on the mean of the two intensities per emotion for accuracy measures reflected the general picture of findings without combining the two intensities per emotion for accuracy and prior to factor analyses for the child symptoms (see Appendix A). In summary, associations between child behaviour and emotion processing were stronger for voices than faces, discrimination accuracy than response bias and externalising than internalising behaviour problems.

Table 3. 7. *Partial Pearson's correlations (p value) between accuracy and child symptoms after controlling for child age in the whole sample (N=57).*

	Child Psychopathology	
Accuracy	Externalising	Internalising
Face		
Angry	-.23(.088)	-.02(.876)
Happy	**-.27(.041)**	.07(.585)
Sad	-.17(.200)	-.19(.165)
Voice		
Angry	**-.35(.009)**	-.04(.762)
Happy	**-.30(.022)**	.09(.515)
Sad	**-.38(.004)**	.01(.926)

Note: Accuracy values represent the mean between the two intensity levels

Table 3. 8. *Full Pearson's correlations (p value) between response bias and child symptoms in the whole sample (N=57).*

	Child Psychopathology	
Bias	Externalising	Internalising
Face		
Angry	-.16(.210)	.07(.579)
Happy	-.06(.608)	-.08(.531)
Sad	.02(.833)	-.12(.364)
Voice		
Angry	-.06(.466)	-.04(.723)
Happy	-.04(.592)	-.07(.583)
Sad	-.03(.808)	.07(.602)

3.5.3 Parent Characteristics

3.5.3.1 Sample Characteristics

Further, the study explored the role of parent characteristics in children's emotion processing. As in the case of child symptoms, the present study followed a dimensional approach to parent psychopathology. The proportion of parents who fell within the atypical range for psychopathology was also explored using the recommended cut-off points (see section 3.3.5). Table 3.9 displays means and standard deviations for parent characteristics in the overall sample.

Table 3. 9. *Means (SD) for parent measures in the overall sample*

	Mean	SD	% atypical
GHQ			
Depression	1.64	2.51	24.6%
ADHD-CBS			
Inattention	.56	1.40	1.8%
Hyperactivity	.91	1.75	5.3%
Combined	1.40	2.97	-
PSOC			
Satisfaction	32.42	6.41	-
Self-Efficacy	25.54	4.26	-
Total PSOC	57.96	9.12	-

Note: GHQ: General Health Questionnaire, ADHD-CBS: Current Behaviour Scale, PSOC: Parenting Sense of Competence.

3.5.3.2 Intercorrelations between Parent Characteristics

Pearson's correlations examined intercorrelations between parent characteristics. Parental symptoms of depression, inattention and hyperactivity, were negatively associated with parenting sense of competence and the satisfaction derived from parenting. In addition, the 'satisfaction' and 'self-efficacy' scales were highly intercorrelated; thus, an aggregated score of 'parenting sense of competence' was created after combining the two scales and used in further analyses. Results are presented in Table 3.10.

Table 3. 10. *Full Pearson's correlations (p value) between parent characteristics*

	Depression	Inattention	Hyperactivity	PSOC	Satisfaction
Depression					
Inattention	.17(.196)				
Hyperactivity	**.30(.023)**	**.77(.001)**			
PSOC	**-.32(.015)**	**-.26(.047)**	**-.32(.016)**		
Satisfaction	**-.29(.026)**	-.22(.101)	**-.32(.015)**	**.90(.001)**	
Self-Efficacy	-.24(.070)	-.23(.080)	-.20(.139)	**.77(.001)**	**.44(.001)**

Note: PSOC= Parenting Sense of Competence.

3.5.3.3 Emotion Processing and Parent Characteristics

In order to examine whether children's accuracy and bias to emotional expressions were associated with parent characteristics, Pearson's partial correlations were conducted. Although child age was not associated with parent characteristics (r=-.2.0, all p's >.12) analyses controlled for child age in the case of accuracy, because child age was significantly associated with accuracy. Bias analyses did not control for child age as child age was not associated with bias. The mean scores between the two intensities per emotion for accuracy were used in analyses.

Results showed a negative relationship between symptoms of parent inattention and children's accuracy for happy and sad faces and angry and sad voices. Symptoms of parent hyperactivity were negatively associated with children's accuracy for angry and sad voices. Symptoms of parental depression were negatively associated with children's accuracy for voices across emotions. Parenting sense of competence was positively associated with children's accuracy for voices across emotions and happy faces. None of these results approached significance when applying Bonferroni correction for multiple comparisons. No significant associations emerged between parent characteristics and children's response bias. Results are presented in Tables 3.11 and 3.12.

Partial Pearson's correlations were conducted controlling for child symptoms, as well as age, because child symptoms were strongly positively associated with parental psychopathology and negatively associated with parenting sense of competence (ps<.001). Results showed no significant associations between parent characteristics and children's accuracy (ps>.08) after controlling for child symptoms. However, there was a tendency for a negative relationship between children's bias to vocal anger and symptoms of parent inattention (r=-.27, p=.053) and hyperactivity (r=-26, p=.062), suggesting that children of parents with externalising symptoms were less likely to attribute anger to vocal expressions. None of these results approached significance when applying Bonferroni correction for multiple comparisons. No other associations reached significance.

Table 3. 11. *Partial Pearson's correlations (p value) between discrimination accuracy and parent characteristics after controlling for child age in the overall sample (N=57).*

Children's Accuracy	Parent Characteristics			
	Inattention	Hyperactivity	Depression	PSOC
Face				
Angry	-.24(.068)	-.17(.204)	-.18(.170)	.21(.121)
Happy	**-.26(.050)**	-.08(.570)	-.18(.165)	**.34(.012)**
Sad	**-.31(.018)**	-.07(.577)	-.23(.092)	.16(.239)
Voice				
Angry	**-.27(.042)**	**-.29(.029)**	**-.29(.033)**	**.29(.029)**
Happy	-.21(.117)	-.20(.129)	**-.27(.046)**	**.26(.053)**
Sad	**-.27(.048)**	**-.26(.057)**	**-.33(.012)**	**.27(.043)**

Note: PSOC= Parenting Sense of Competence.

Table 3. 12. *Full Pearson's correlations (p value) between bias and parent characteristics*

Children's Bias	Parent Characteristics			
	Inattention	Hyperactivity	Depression	PSOC
Face				
Angry	-.10(.430)	-.02(.850)	-.05(.677)	.03(.819)
Happy	-.14(.276)	-.09(.467)	-.09(.506)	.06(.649)
Sad	-.09(.482)	.00(.994)	-.03(.776)	.04(.739)
Voice				
Angry	-.19(.143)	-.21(.106)	.01(.918)	.14(.289)
Happy	-.06(.655)	-.04(.764)	.01(.925)	.09(.950)
Sad	-.09(.485)	-.07(.571)	-.02(.851)	-.10(.440)

Note: PSOC= Parenting Sense of Competence.

3.6 Discussion

The aim of the present study was to explore associations between discrimination accuracy and response bias to facial and vocal emotional expressions and behaviour problems in preschoolers. Grounded in theoretical models of social information processing (Dodge, Bates, et al., 1990), the present study explored emotion processing in children with behaviour problems and extended previous research by incorporating vocal emotion as well as facial emotion and by focusing on recognition during the preschool years.

Initial analyses aimed to establish whether the emotion recognition task worked well with preschoolers. Results indicated that preschoolers, overall, could accurately recognise facial expressions across a range of emotions at above chance levels. Children were more accurate at recognising angry compared to sad faces and happy compared to sad faces. Children in the present study were equally accurate to identify angry and happy faces. This pattern of results only slightly differs from accuracy rates reported in previous studies with preschoolers (Camras & Allison, 1985; Martin et al., 2010; Philippot & Feldman, 1990), showing higher accuracy for happy compared to angry and sad faces, although some of these studies used different tasks such as matching tasks and social stories. A possible explanation for the current findings could be that sad faces are less frequent social cues in children's daily experiences which might explain children's reduced sensitivity to sad faces.

Overall recognition accuracy of vocal expressions was also above chance level and similar to those of previous studies with preschoolers (Mitchell, 1995; Verbeek, 1996). Recognition accuracy was higher for angry than happy, angry than sad and sad compared to happy voices. Similar patterns of results have been reported in earlier work with preschoolers (Hortacsu & Ekinci, 1992). Preschool children found it easier to identify angry compared with happy voices, perhaps because angry voices represent salient threatening and punishing social signals. Happy voices were the most difficult to recognise. This is consistent with previous research showing that although happiness is more easily recognisable from facial expression (Ekman, 1994), it is more difficult to identify in vocal expressions (Elfenbein & Ambady, 2002; Scherer, Schorr, et al., 2001; review by Scherer, 2003; Scherer, Banse, & Wallbott, 2001). Nevertheless, one cannot exclude the possibility that happy items may not have captured adequately the positive valence of the expression and were, therefore, recognised with the lowest accuracy. Future studies should aim to further develop vocal emotional stimuli.

Regarding modality effects, results showed that preschoolers were significantly better at recognising facial than vocal expressions across all emotion conditions. Earlier studies have shown comparable accuracy rates for faces and voices (Stifter & Fox, 1986). A possible explanation for the present finding could be that faces are less abstract and more direct and accessible visual cues compared to auditory signals for typically developing children. Results suggested a developmental pattern for emotion recognition accuracy for both facial and vocal modalities consistent with prior research with preschoolers (Baum & Nowicki, 1998; Boyatzis et al., 1993; Rothman & Nowicki, 2004; Widen & Russell, 2003; Widen & Russell, 2008). The study showed no gender differences in recognition accuracy. Although some studies have shown a female advantage in processing emotional faces and voices (Barth & Bastiani, 1997; Boyatzis et al., 1993; review by McClure, 2000), this finding is not consistent across studies.

In relation to bias, children showed higher bias to sad than angry and happy than angry facial expressions and sad than happy vocal expressions. The above results seem to be consistent with findings from recent research with preschoolers showing a higher bias to sadness compared to anger and happiness (Martin et al., 2010). A developmental pattern in bias was not evident and there were no gender effects either. This supports previous research with preschoolers showing that bias is more stable compared to accuracy over time (Barth & Bastiani, 1997; Schultz et al., 2004). This stability of bias over time may have important implications for atypical development. In regards to modality specific effects on bias, preschoolers presented a higher tendency to attribute anger to voices compared to faces (bias to vocal anger) but a greater tendency to attribute happiness to faces compared to voices (bias to facial happiness). This tendency may be explained by children's greater exposure to happy faces and angry voices in daily social interactions with caregivers.

In respect to psychopathology, a key finding of the present study was a negative association between externalising symptoms and children's accuracy for vocal emotional expressions, especially negative expressions, such as sadness and anger. Reduced sensitivity to facial sadness and anger has been reported previously in school-aged children (Corbett & Glidden, 2000; Da Fonseca et al., 2009; Kats-Gold et al., 2007; Pelc et al., 2006) and preschoolers (Martin et al., 2010) with externalising symptoms, suggesting that sadness and anger may have a key role to play in the emotion regulation strategies of children with externalising symptoms. The present study extends these deficits to vocal expressions and highlights the importance of focusing on vocal anger in future studies.

The finding that children with externalising symptoms presented lower recognition accuracy for vocal sadness and anger has important implications for future research. It could be hypothesised that children with externalising behaviour problems have a specific difficulty in recognising vocal signals of distress (i.e. sadness) or threat (i.e. anger) in others which may explain part of their difficulties to show empathy or adapt to punishing social signals. In either case, the fact that children with externalising symptoms are less accurate at perceiving anger in adult voices might suggest that adult vocal messages displaying anger would possibly need more time and effort to get through to this group of children. Findings may have implications for parenting practices.

Surprisingly and contrary to prior research (Corbett & Glidden, 2000; Kats-Gold et al., 2007; Pelc et al., 2006; Singh et al., 1998), associations between children's externalising behaviour and facial expression recognition were less strong compared with vocal expressions. These findings of the present study are consistent with Shapiro and colleagues (1993) and Norvilitis and colleagues (2000) who found deficits in vocal but not facial expression recognition in school-aged children with hyperactivity, although the first study assessed emotion recognition through complex cross-modal matching tasks, placing increased demands on children's auditory processing and working memory. The fact that only vocal expressions were associated with externalising behaviour in the present study further highlights the significance of integrating measures of vocal emotion recognition in future studies.

Some candidate explanations can be suggested for the above finding. First, the above mentioned studies included school-aged children whereas the present study focused on the preschool years. It is possible that younger children may rely predominantly on auditory, as opposed to visual, cues and that the latter might require more advanced processing encountered in older children (Napolitano & Sloutsky, 2004; Shackman & Pollak, 2005). A developmental study would be required to address this question. Second, faces were recognised at higher accuracy compared to voices and it could be postulated that faces were 'easier' to recognise by preschoolers in the present study and for this reason failed to show sensitivity to individual differences in children with behaviour problems.

Comorbidity between hyperactivity and conduct problems, expressed under the 'externalising' umbrella in this study, might also have a role to play in terms of explaining the patterns of the above associations. In the present study, the few facial emotion recognition difficulties observed were specific to hyperactivity whereas difficulties in vocal emotion recognition related to both conduct problems and hyperactivity and were not emotion specific (see Appendix A). Thus, voice processing difficulties may characterise children with externalising symptoms independently of emotion type and comorbid conditions (i.e. hyperactivity and conduct problems). It should be noted, however, that the level of conduct problems was higher (50.9%) in the present sample compared to hyperactivity (31.6%) which may partly explain the greater number of associations with conduct problems. Previous studies have shown that facial emotion recognition did not differ between controls and children with comorbid hyperactivity and conduct problems (Corbett & Glidden, 2000; Guyer et al., 2007). Earlier work found that children with conduct problems were even more accurate compared to controls in identifying facial emotions (Ellis et al., 1997). Vocal emotion recognition deficits have previously been reported in a small sample of school-aged children with conduct problems and psychopathic tendencies (Stevens et al., 2001). The present study extends these findings to the preschool years and demonstrates that such deficits extend to the whole externalising spectrum.

The current findings do not support previous research linking conduct problems to recognition biases toward anger in preschoolers (Barth & Bastiani, 1997; Dodge, Bates, et al., 1990; Schultz et al., 2000; Schultz et al., 2004) and older children (Crick & Dodge, 1994; Crick & Dodge, 1996; de Castro et al., 2005). An 'over processing' of anger (i.e. anger bias) reported in hyperactive school-aged children (Ellis et al., 1997; Manassis et al., 2007) and adolescents (Williams et al., 2008), was not evident in this study with preschoolers. Similarly, the study did not support links between processing biases and internalising symptoms contrary to prior research (Garner, Mogg, & Bradley, 2006; Hadwin et al., 2003; Perez-Olivas et al., 2008; Stirling et al., 2006), suggesting that biases reported in school-aged children may not manifest during the preschool years. However, the vast heterogeneity of child symptoms could account for the picture of the present findings. In addition, because recognition accuracy in the present study was high and the tendency to misattribute emotions (bias) was relatively low, this might not have allowed for individual differences in bias to emerge.

Finally, the present study explored the role of parent characteristics in children's performance. The study found that children's recognition accuracy was positively associated with parenting sense of competence and negatively associated with parental psychopathology. Parental depressive symptoms and hyperactivity showed a number of negative associations with children's vocal emotion recognition, especially sadness and anger. Negative (i.e. angry) emotions displayed by voices may potentially have a salient role in the communication patterns of children with hyperactive parents. These results support findings from Norvilitis and colleagues (2000) showing reduced emotion recognition accuracy in children of hyperactive parents. However, when child symptoms were taken into account in the present study, there was a tendency for a reduced vocal anger bias in children of parents with externalising symptoms, suggesting that children were less likely to attribute anger to vocal expressions.

The relationship between parental externalising psychopathology and children's vocal anger biases highlights the contribution of early environments to children's emotion processing, although caution should be taken as the effects were only marginal and none were significant following Bonferroni correction. Previous work (Shackman & Pollak, 2005) has shown that early experiences can influence the perception of vocal anger in children, although this study examined abused children. Previous research has shown that parental expression of anger toward the child was related to lower levels of children's understanding of anger (Garner, Jones, & Miner, 1994). Externalising behaviour problems have previously been associated with parental anger (Eisenberg et al., 2001; Halberstadt et al., 1999) and intensity of maternal vocal expressions (Shackman et al., 2010).

This study presents a number of limitations which future studies should address. First, it is not clear whether low accuracy for vocal emotional expressions in the present study reflects emotion-specific effects or properties of the stimuli used. For example, the validation phase of vocal items showed a low rate of agreement among adult judges on the vocal, especially happy, items which may explain the lower rates of recognition for vocal happiness in preschoolers. Future studies should aim to further develop and validate the vocal stimuli. In addition, the semantic message *'I will go out of the room now...etc'* conveyed by the vocal expressions may have influenced children's judgement of emotion expressed by the speaker (i.e. negative/sad) possibly explained by the higher tendency to attribute sadness and anger to voices in this study. Such distracting effects of language on emotion processing have been reported in previous research with children (Morton & Trehub, 2007).

In healthy adult individuals the average agreement of 78% on recognising facial emotional expressions of basic emotion suggests that emotional expressions can be classified above chance levels when presented as facial photographs (Ekman & Friesen, 1971). Similarly, adult listeners can infer a speaker's emotions from vocal cues at above chance levels (Banse & Scherer, 1986). In the present study, children recognised facial emotional expressions at high accuracy rates which approximated those observed in adult individuals. Therefore, a negative relationship between externalising symptoms and accuracy for facial emotional expressions would reflect a true deficit in recognising that specific expression rather than the fact that facial emotional expressions were difficult to recognize. However, in the present study, although children recognised vocal emotional expressions at above chance level, recognition accuracy for vocal expressions was generally low. Therefore, one cannot exclude the possibility that a negative relationship between externalising symptoms and accuracy for vocal expressions may reflect the fact that vocal expressions are difficult to recognise during the preschool years rather than a real deficit in recognizing vocal expressions. A developmental study assessing vocal emotion recognition in children of different ages would be very informative in this regard.

Second, following further development of vocal stimuli, future studies should aim to examine whether the above associations between vocal expressions and child symptoms are developmentally sensitive in nature by studying vocal emotion recognition at different ages and links to psychopathology. As studies with school-aged children with behaviour problems have found evidence for facial emotion processing difficulties, it is important to examine whether the voice-specific difficulties, found in the present study, would be present in later stages in development or limited to the preschool years (Herba et al., 2006; Tonks et al., 2007). A developmental study would be required to address this issue. In parallel, a developmental study would allow to further validate vocal stimuli in a wider number of children of different ages.

Third, the study revealed negative associations between children's externalising symptoms and vocal expression recognition accuracy. Two limitations to these results are of note. First, it is possible that recruitment of children from two different sources (clinic and community) may have influenced the relationship between children's emotion recognition abilities and externalising behaviour problems because of differences in group means of the two variables (emotion recognition and externalising behaviour). Separate correlational analyses for the community and clinic referred sample revealed non-significant but negative Pearson's correlations between emotion recognition and externalising problems (Angry: $r=-.28$, $p=.16$, Happy: $r=-.26$, $p=.17$, Sad: $r=-.33$, $p=.091$) which would allay the above concerns.

Second, the associations observed in the present study between emotion recognition and externalising behaviour problems, were not emotion-specific. One cannot exclude the possibility that the impairment is due to a perceptual impairment unrelated to emotional content. The possibility that a general voice processing difficulty rather than an emotion-specific difficulty underlies such deficits was examined by looking at children's processing of neutral (non-emotional) stimuli. In contrast to the significant associations observed with emotional faces, associations between externalising problems and accuracy for neutral (non-emotional) faces ($r=-.12$, $p=.38$) and voices ($r=-.17$, $p=.19$) were not significant. This was also the case when these associations were examined independently in clinic-referred and community samples. This suggests that the impairment may be specific to emotional than non-emotional (neutral) stimuli.

Regarding effects of parent characteristics on children's emotion processing, the study showed that parental psychopathology was negatively associated with children's emotion recognition accuracy. However, it should be emphasised that the interpetation of these findings are ambiguous. A negative relationship between parental psychopathology and children's emotion recognition accuracy might suggest either the influence of parental psychopathology on the environment (i.e. through parenting behaviour, modelling etc.) or an increased likelihood of a child carrying risk genes for emotion processing deficits. In the absence of a genetic design results need to be treated with caution.

Finally, this study did not include measures of intellectual functioning; however, research has consistently shown that vocal emotion recognition was unrelated to IQ in preschoolers (Baum & Nowicki, 1998; Mitchell, 1995; Rothman & Nowicki, 2004). Also, this study did not employ a face recognition task to assess general face processing abilities in preschoolers. However, previous developmental research has suggested that face recognition is mature in the preschool years (de Heering, Houthuys, & Rossion, 2007).

In conclusion, this study provided further insight into emotion processing in young children with behaviour problems. It demonstrated links between vocal emotion processing difficulties and externalising symptoms in children. Future studies should further develop the vocal stimuli in a larger number of children at different stages in development and untimately examine the underlying cognitive components of such deficits.

Chapter 4. A Developmental Study in the Recognition of Facial and Vocal Emotion

4.1 General Introduction

Study 1 showed negative associations between child externalising symptoms and vocal emotion recognition in preschoolers. Vocal emotional expressions used in Study 1 consisted of the sentence *'I will go out of the room now etc.'* spoken with angry, happy, sad and neutral tone of voice. These stimuli worked well but they were limited by their linguistic content. It was unclear from the previous study whether preschoolers showed difficulties in recognising emotional voices because of a difficulty in interpreting emotional prosody or because of difficulty in processing the linguistic structure underlying the emotional prosody. The present study aimed to examine children's perception of emotional prosody independently of linguistic and semantic processing demands.

Developmental research has demonstrated differential effects of vocal stimuli properties (prosody compared to speech) on recognition accuracy. Research has shown that infants respond differentially to speech over non-speech sounds (Vouloumanos & Werker, 2004). Research with preschoolers found that 4-year-old children relied on language content to infer emotion from vocal expressions, compared to adults who relied on emotional prosody, and that with age there was a gradual shift away from content and increasing attention to the speaker's prosodic cues (Morton & Trehub, 2001). Six-year-olds were more likely to respond to language content than to emotional prosody when these cues conflicted (Morton & Trehub, 2001). Research has shown that 6-year-olds could judge emotion from prosodic cues in the presence of competing content, but that they often remained focused on content (Morton, Trehub, & Zelazo, 2003). A recent study on interpretation of vocal emotion from songs with lyrics showed that adults judged the singer's emotional state from vocal tone but 5- to 10-year-olds based their judgements on the lyrics (Morton & Trehub, 2007).

There is some evidence that language content and prosodic aspects of processing may involve different brain regions. Research has found independent functional pathways in the brain, including posterior superior temporal sulcus (STS) in the left hemisphere, for analysis of speech information and temporo-medial regions and the insula predominantly in the right hemisphere for analysis of vocal affective information (Belin, Fecteau, & Bédard, 2004). Additional studies have revealed laterality effects for processing of emotional prosody and emotional semantics in adults (Ethofer, De Ville, Scherer, & Vuilleumier, 2009). Specifically, the content of the emotional voices activated the left prefrontal cortex whereas the emotional prosody activated the right prefrontal cortex (George, Parekh, et al., 1996; Wildgruber, Ackermann, Krelfelts, & Ethofer, 2006), although other studies have argued that processing emotional prosody is mediated by bilateral mechanisms (Morris, Scott, & Dolan, 1999; Schirmer & Kotz, 2006).

In light of the above evidence, Study 2 aimed to identify and validate a set of vocal stimuli without language content for use in Study 3. Study 3 examined the development of facial and vocal emotion processing and links to psychopathology.

A first aim of Study 3 was to examine the development of facial and vocal emotional expression recognition. Previous research has shown a developmental pattern in the recognition of emotion from facial expressions (Montirosso et al., 2010; Vicari et al., 2000; Widen & Russell, 2003). For example, five and a half year olds demonstrated higher accuracy than 3-year-olds in recognising emotional faces (Boyatzis et al., 1993). The majority of developmental studies in facial emotion recognition have focused on early to late childhood (i.e. 4, 6 and 8-year-old children) (Batty & Taylor, 2006; Durand et al., 2007; Markham & Adams, 1992; Vicari et al., 2000). Behavioural studies have also shown that pre-adolescence (at 11 years) marked an important developmental stage for facial emotion recognition (Tonks et al., 2007). Finally, previous research has suggested that the developmental course of facial emotion processing is dependent on the emotion type (Durand et al., 2007; Herba et al., 2006) and intensity level (Montirosso et al., 2010).

The developmental literature suggests that the ability to recognise emotions from the tone of voice improves with age (Baum & Nowicki, 1998; Hortacsu & Ekinci, 1992; Maxim & Nowicki, 1997; McClanahan, 1996; Rothman & Nowicki, 2004; Rowe, 1996). The period from 4 to 9 years of age, in particular, has been found to represent a developmental period of growth in sensitivity to emotions displayed from vocal cues. For example, a recent study showed that 4 but not 3-year-olds, used vocal affect cues to judge speakers' intentions about objects referred to during speech (Berman, Chambers, & Graham, 2010). Six year-olds were better able than 4-year-olds to judge emotion from prosodic cues in songs (Morton et al., 2003). Finally, the ability to understand emotions from musical cues developed rapidly in 6, 8 and 10-year-old children (Morton & Trehub, 2007).

A second aim of Study 3 was to explore associations between facial and vocal emotion processing and psychopathology in 4- to 10-year-old children and adults. Study 1 showed a negative relationship between externalising symptoms and recognition accuracy for vocal emotions. Previous research suggests that facial emotion recognition difficulties in children with externalising problems may change with development (Guyer et al., 2007; Pelc et al., 2006). Study 3 examined whether such developmental effects would generalise to vocal emotion processing difficulties found in Study 1.

4.2.1 Introduction

Further studies in this thesis aimed to use a set of vocal stimuli devoid of linguistic content in order to examine children's vocal emotion processing independently of linguistic processing demands.

First, Study 2 aimed to identify a set of emotional prosody stimuli. This entailed identifying a battery of angry, happy, sad and neutral vocal stimuli without language content. In addition, as emotional prosody in real-life is displayed at varying levels of intensity (Montagne et al., 2007) and in line with Study 1, intensity was retained as a factor in Study 2 in order to examine different levels of difficulty (low-50% compared to high-75% intensity) in processing vocal emotion (Nowicki & Mitchell, 1998) and capture differences in emotional processing in an ecologically valid way.

As described in Chapter 1, emotional prosody refers to changes in the intonation of the voice according to the speaker's feelings and emotional state (Hargrove, 1997) and is related to changes in the voice fundamental frequency (F0), giving rise to a melody contour in the voice (Banse & Scherer, 1996). Social communication is characterised by a wealth of verbal and non-verbal utterances expressing emotion including exclamations (i.e. wow!), interjections (i.e. ah!) and non-speech sounds (i.e. laughter, crying) (Scherer et al., 1991; Schröder, 2003). Defining and measuring emotional prosody, in a comprehensive and meaningful way, has been a major challenge for emotion researchers (Scherer, 2005). A systematic search of the literature on this topic revealed five relevant validated batteries measuring emotional prosody in adults (see Table 4.1). Some of these batteries contained stimuli that were very short in duration (i.e. 500 ms) (Grimshaw, 1998) or that contained linguistic content (Baum & Nowicki, 1998), including pseudowords such as 'gosterr' (Banse & Scherer, 1996), whilst others included affective bursts, such as laughing and crying (Belin, Fillion-Bilodeau, & Gosselin, 2008).

After considering the above options, the present study selected a recently validated battery of vocal emotional expressions (Maurage et al., 2007) consisting of the vowel /a/ (/a/ as in apple) expressed in angry, happy, sad and neutral tone of voice. This battery presented a number of advantages over other batteries: 1) it is validated through a double validation phase consisting of expert ratings and a large validation phase with 70 adult participants, 2) it is standardised and includes controlled duration and intensity of the stimuli 3) it was found to have high internal consistency (a=.82) for each emotion set (e.g. happy) and high levels of specificity (independence between the ratings in the different emotion sets – p >.40) 4) it was found to have high mean intensity ratings (M= 5.5, SD=.02) for each emotion in a 1-7 point scale. Last but not least, this battery was recommended for use in electrophysiological research (Maurage et al., 2007).

Second, following the successful identification of a suitable battery, Study 2, aimed to provide a pilot validation of the vocal emotional expressions adopted. Study 2 was a preliminary small-scale validation study of the new vocal stimuli in 40 participants which identified stimuli most suitable for use in Study 3. The aim was to select vocal stimuli that could be recognised by children at above chance levels of accuracy. Previous research using vocal stimuli with language content has found recognition accuracy rates of 40-50% in 4-year-olds (Mitchell & Nowicki, 1998; Narayan & Hartson, 2000) and about 70% in 8-year-olds (Maxim & Nowicki, 1998) in tasks with four emotions as response options. A meta-analysis of adult studies in vocal emotion recognition cross-culturally, found an overall accuracy of 63.7%, 62.8% and 28.9% for the recognition of angry, sad and happy voices respectively (Elfenbein & Ambady, 2002). Other adult studies using speech-stimuli have shown accuracy rates of 77%, 71% and 57% for angry, sad and happy stimuli respectively (Scherer, Banse, et al., 2001). Research in adults using non-speech vocalisations has shown a mean recognition accuracy of 68% for 8 emotions (Belin et al., 2008).

4.2.2 Aims

The aims of the present study were as follows:

1. To identify a vocal emotional expression battery of emotional prosody for use in subsequent studies.

2. To provide a pilot validation of this new battery of vocal emotional expressions in children and adults

Table 4. 1. *Features of the five candidate batteries of vocal stimuli considered prior to selection of a vocal stimuli battery for subsequent studies*

	DAVNA-AP-2 (Baum & Nowicki,1998)	Maurage et al., 2007	Montreal Affective Voices (Belin et al., 2008)	Banse & Scherer, 1996	Grimshaw, 1998
Participants	Children and adults	70 adults	30 adults	12 adults	32 adults
Methods	Behavioural	ERP	Behavioural	fMRI	Brain laterality
Content	Sentence *'I will go out of the room now etc.'* with American accent.	Interjection /ah/	Natural vocalisation /a/ (i.e. laughing, crying)	Meaningless utterance ('gosterr')	Words *mad, glad, sad, fad*
Emotion	angry, happy, sad and fearful	angry, happy, sad, fearful, disgust, neutral	angry, happy, sad, fearful, pleasure, pain, surprise, neutral	angry, happy, fearful despair, sad, elation etc.	angry, happy, sad
Duration	3000 ms	700 ms	253 ms- 4.300 ms	750-2000 ms	550 ms
Intensity	High and low intensity	100% (75 and 50% also available)	Varying intensities	Varying intensities	100%

4.2.3 Methods

4.2.3.1 Participants

A total of 40 healthy English native speakers from the community participated in this pilot validation study. The overall sample consisted of 22 adults (age range 24-58 years, mean age=31.54, SD=9.36, 14 girls) and 18 children (age range 5.50–7.50 years, mean age=6.60, SD=.70, range=2 years, 7 girls). School-teachers were asked to recommend children with no hearing difficulties on the basis of school records. Adults with no hearing difficulties were selected on the basis of self-report.

4.2.3.2 Vocal Stimuli

In order to assess emotion perception, a version of the selected battery was employed containing vocal stimuli of emotional prosody of varying intensity, including a moderate (50%) and a high (75%) intensity level (Maurage et al., 2007). The stimuli were normalised and standardised with respect to acoustic properties including 700 ms duration, 1600 Hz frequency, 70 dB intensity leading to a correspondent SPL of 0.063 Pa. The vocal stimuli included an angry, happy, sad and neutral interjection /a/. The stimulus material consisted of combinations of 3 emotions (angry, happy and sad) x 2 intensities (50%, 75%) x 5 female actors (standard feature of the battery) plus five neutral items leading to 35 items in total. Only ambiguous (of varying intensity) stimuli from the selected battery were included in this preliminary validation study. Full intensity (100%) stimuli were excluded. The full intensity (100%) items were not included for validation in this study on the premise that they had already been validated in a large sample of adults in previous research (Maurage et al., 2007).

4.2.3.3 Vocal Emotion Rating Task

Participants listened to each of the 35 vocal items and rated whether it was ‘*angry’*, ‘*happy’*, ‘*sad’* or ‘*neutral’*. After selecting one (emotion) word per vocal item, participants indicated how intense the emotion they had chosen (i.e. angry) was on a 1-8 scale (adults) and 1-4 scale (children), for instance, from ‘*not at all angry’* to ‘*extremely angry’*. Ratings from the adult and children’s scale were standardised to generate a unified 1-4 intensity scale to facilitate comparison between the groups. Adults recorded their responses on a rating sheet. Children listened to one vocal item at a time. Following this, the experimenter read four response options out to the child (was the voice angry, happy, sad or okay?) x 6 (possible combinations of emotion words in counterbalanced order across trials). Following the child's response (i.e. angry), the researcher pointed to an equivalent (i.e. angry) face drawing and asked the child to indicate how intense the emotion was by pointing to one of four variably sized face drawings (see Appendix B). Children's responses were recorded on a response sheet by the researcher. The validity of these face drawings (Voyer, Bowes, & Soraggi, 2009), as an accurate reflection of the emotion they depicted, has been demonstrated in a sample of 67 adults with a recognition rate of 100% for both happy and angry drawings, 98.5% for the sad and 94% for the neutral drawing (Techentin, Voyer, & Klein, 2009).

4.2.3.4 Procedure

Approval for this study was granted by the School of Psychology Ethics committee, University of Southampton. Information about the study was provided to Head teachers, the parents of children participating in the study and adult participants. Children were approached through local primary schools, following parental and teacher consent. Child assent and adult consent was obtained prior to participation in the study. Adults were a convenience sample consisting of students from the University of Southampton. Children took part in the study in a quiet room of their school and adults at the University.

4.2.4 Results

4.2.4.1 Recognition Accuracy

For the purposes of this pilot study, the mean agreement (%) among participants on the identification of a particular emotion was calculated. The mean agreement in the overall sample was 50% which was two times higher than what would be expected if participants had performed at chance level (defined as 25% for four response options). Angry expressions reached the highest mean agreement (68.50%) compared to happy and sad expressions. Mean agreement on the neutral vocal expressions in children was low (27.28%). The mean agreement for adults, children and overall sample by emotion and intensity category is presented in Table 4.2. The mean agreement item by item in adults, children and the overall sample is presented in Appendix B.

Table 4. 2. *Mean agreement (%) for the vocal items per emotion and intensity category in adults, children and the total sample.*

	Angry			Happy			Sad			Neutral		
Expression	Adult	Child	Total	Adult	Child	Total	Adult	Child	Total	Adult	Child	Total
Angry 50%	**60.00**	**42.22**	**52.00**	5.44	20.00	12.00	23.66	32.20	27.50	10.90	5.58	22.50
Angry 75%	**84.56**	**48.88**	**68.50**	6.34	21.10	13.00	5.46	18.88	11.50	3.62	10.00	6.50
Happy50%	24.54	21.24	23.00	**43.64**	**38.90**	**41.50**	11.82	31.10	25.00	10.92	8.90	10.00
Happy75%	17.26	22.2	19.50	**57.28**	**42.22**	**50.50**	18.18	25.56	21.50	7.28	10.02	8.50
Sad 50%	5.42	14.46	9.50	7.26	26.66	16.00	**40.92**	**44.44**	**42.50**	43.64	13.34	30.00
Sad 75%	9.08	16.66	12.50	0.90	16.70	8.00	**61.82**	**44.44**	**54.00**	27.26	20.02	24.00
Neutral	3.62	14.44	8.50	10.00	20.00	11.40	21.80	37.78	29.00	**64.56**	**27.28**	**48.00**

4.2.4.2 Misattribution Patterns

Overall, the strongest pattern of confusion was observed between sad and neutral expressions. A second pattern of confusion was that between sad and happy expressions. Finally, there was a tendency for participants to classify angry items of low intensity as sad. Children presented a higher tendency to confuse emotions compared to adults (see Table 4.2).

4.2.4.3 Intensity Ratings

Analyses of the intensity ratings showed that vocal items of high intensity level (75%) achieved higher intensity ratings (on a 1-4 point scale) compared to items of low intensity level (50%). In addition, angry vocal items reached higher intensity ratings followed by happy and sad items, which was in general agreement, with the accuracy findings. The number of vocal items classified as *'angry'*, *'happy'*, *'sad'* and *'neutral'* and their mean intensity ratings across participants are presented in Appendix B.

4.2.5 Discussion

The aim of Study 2 was twofold; first to identify a battery of vocal emotional stimuli to use in Study 3 and second, to provide a pilot validation of these vocal stimuli.

First, Study 2 identified a set of suitable stimuli of emotional prosody. A battery of angry, happy, sad and neutral stimuli presented a number of advantages over other batteries (Maurage et al., 2007). These stimuli were devoid of linguistic content and were presented at different intensities, including a 50% and a 75% level of intensity.

Second, the above stimuli were validated and so informed the selection of appropriate stimuli for use in Study 3. In Study 2, children and adults identified emotions in prosody at an overall accuracy of 50% (two times higher than chance level performance at 25% given the four response options), which shows that prosodic cues are an effective means of expressing vocal emotion. This rate is consistent with accuracy rates (i.e. 55-66%) reported in the adult literature of vocal emotion recognition using speech stimuli of short-duration (Banse & Scherer, 1996). Research with children with speech stimuli has found accuracy rates of 50% in preschoolers (Mitchell & Nowicki, 1998; Narayan & Hartson, 2000) and approximately 70% in older children (Maxim & Nowicki, 1998; McClure & Nowicki, 2001; McClure, 2001) in tasks with four reponse options. In Study 2, children were less accurate compared to adults in recognising emotions from prosody, suggesting a developmental pattern in vocal emotion recognition.

Regarding emotion specific patterns, Study 2 found higher mean agreement among raters for anger compared to happiness and sadness; this was supported by the intensity ratings showing that anger achieved the highest mean intensity rating relative to other emotions. Higher accuracy for vocal anger compared to other emotions was found in Study 1 and previous research with preschool children (Baum & Nowicki, 1998; Mitchell & Nowicki, 1998). Previous studies in adults have found higher accuracy rates for angry compared to happy and sad vocal items using linguistic (Banse & Scherer, 1996; Scherer, Banse, et al., 2001) and prosodic (Maurage et al., 2007) stimuli. This is also consistent with previous adult research using vocal stimuli with language content (Elfenbein & Ambady, 2002). As vocal anger is characterised by increased mean fundamental frequency (F0) and mean energy (i.e. loudness) (Banse & Scherer, 1996; review by Juslin & Laukka, 2003), it can be argued that acoustic profiles for vocal anger are highly specific and easier to recognise (Laukka, 2004).

Study 2 examined possible misattribution tendencies, consistent with previous research highlighting the importance of considering error patterns (confusion matrices) in vocal emotion recognition (Johnstone & Scherer, 2000; Wagner, 1993). Patterns of errors are valuable because they provide information on the nature of the inference process (Banse & Scherer, 1996). In Study 2 participants, and especially children, tended to classify angry and neutral expressions as ‘sad’. Participants confused anger with sadness (perhaps because sadness and anger are both items of negative valence). These results are in agreement with Study 1, showing a higher bias to vocal sadness in preschoolers. This consistency across studies provides some reassurance that the present task captured real effects. In addition, 43% of adults tended to classify low intensity sad items as neutral. Other research has shown that vocal sadness is one of the most commonly confused emotions (review by Juslin & Laukka, 2003).

In summary, Study 2 identified a suitable battery of vocal stimuli and provided some preliminary information on the validity of the vocal stimuli in children. To corroborate the validity of the stimuli in a larger sample of participants and systematically examine effects of age, intensity and emotion type on accuracy, further investigation was necessary. This task was undertaken in a large developmental study (Study 3).

4.3 Study 3-The Development of Facial and Vocal Emotion Processing and Links to Psychopathology.

4.3.1 Introduction

Following the pilot study of the new vocal stimuli, the first aim of Study 3 was to examine the development of facial and vocal emotion processing in 4- to 10-year-old children.

4.3.1.1 Facial Emotion Processing

A developmental milestone in facial emotion recognition accuracy is the period from early to middle childhood (Batty & Taylor, 2006; Markham & Adams, 1992; Vicari et al., 2000). However, few developmental studies have included adult comparison groups despite evidence that facial emotion recognition continues to develop from adolescence to adulthood (Thomas, De Bellis, et al., 2007). In addition, the developmental course of facial emotion processing is dependent on the emotion type. For example, 4- to 15-year-olds showed a steep developmental increase in recognition accuracy for happy and sad, but not angry faces (Herba et al., 2006), whilst other studies found more pronounced developmental patterns for angry faces in children and adolescents (Durand et al., 2007; Thomas, De Bellis, et al., 2007). Further evidence is important to clarify emotion-specific developmental trajectories.

Chapter 1 argued that part of the inconsistency in the above findings may be explained by different methodologies. For example, the ability to recognise happy faces was at ceiling levels for matching tasks but significantly poorer for memory tasks, in particular for younger children (Vicari et al., 2000). This suggests an improvement in memory of emotional faces with development. In the same study, accuracy for disgust was higher for recognition tasks (i.e. naming emotions in a story context) compared to labelling tasks (i.e. provide verbal labels for facial photographs), consistent with research showing that ‘disgust’ is acquired later in development as a verbal label (Widen & Russell, 2008). Research in 4- to 15-year-olds has found gradual improvement in the ability to recognise different intensity facial expressions (Montirosso et al., 2010). For example, in the same study, school-aged children presented lower accuracy compared to adolescents in recognising low (i.e. 50%) compared to high intensity emotional expressions. Also, preschoolers were less accurate than school-aged children and adolescents in recognising low intensity (i.e. 50%) faces, however, they did not differ from 8-year-olds (Montirosso et al., 2010). It has also been shown that adolescents were less accurate than adults in recognising low intensity expressions (Thomas, De Bellis, et al., 2007). Exploration of emotion processing with different intensities allows an opportunity to examine response bias. The study of response bias is important in understanding the pattern of decision criteria and the inference process underlying emotion recognition (review by Scherer, 2003) and it has been shown to be closely linked to children's social adjustment (Barth & Bastiani, 1997).

4.3.1.2 Vocal Emotion Processing

Developmental milestones in vocal emotion recognition accuracy highlighted by previous research include the ages of 4, 6 and 8 years (Berman et al., 2010; Morton & Trehub, 2007; Morton et al., 2003). There is also some convergence among studies that sensitivity to vocal emotional expressions continues to develop from the preschool years through to early adolescence reaching adult-like levels at about 10 years of age (Baum & Nowicki, 1998). Tonks and colleagues (2007), for example, examined the development of perception of the six basic vocal emotions in a sample of 77 9- to 15-year-olds, using semantically neutral sentences and found no improvement with age in vocal emotion processing across a number of tasks, including emotional prosody matching tasks, verbal labelling of prosody and identification of congruency between prosody and semantic message. Accuracy rates in this study were above 80% from 9 to 15 years, suggesting that from late childhood to adolescence these abilities reached adult-like levels of recognition (Tonks et al., 2007). Similar rates of recognition accuracy were found in a recent study with 9-year-old-children using semantically neutral angry, happy and sad face-voice pairs (Shackman et al., 2007).

Less is known about developmental effects on the recognition of specific emotions from vocal expressions. Early research, for example, has shown that younger children (3- to 4-year-olds) were equally accurate in identifying anger, happiness and sadness from voices, while older (5-year-old) children and adults made more incorrect responses when identifying sad voices in particular (Stifter & Fox, 1986). Current reviews of vocal emotion processing (Juslin & Laukka, 2003) highlight the need for further investigations to elucidate emotion-specific developmental trajectories in vocal recognition accuracy. Finally, existing studies have not included adult comparison groups to establish when an adult-like level of performance for specific emotions is reached.

The focus of developmental research has been on the categorical perception of emotional expressions and there is a relevant paucity of studies examining the role of intensity on recognition accuracy and how these effects change with development. The intensity of vocal emotional expressions is informative for capturing more subtle change in children's emotion understanding. Varying intensity represents an ecologically valid and important component of sensitivity to emotional voices; it allows a more specific determination of decoding difficulties (Baum & Nowicki, 1998) and an opportunity to explore associations with social adjustment in children (Mitchell, 1995; Verbeek, 1996). In summary, the present study aimed to address the above limitations by focusing on the developmental periods highlighted as important milestones by previous research.

4.3.1.3 Emotion Processing and Psychopathology

A second aim of Study 3 was to explore associations between emotion processing and psychopathology in children and adults. Developmental research suggests that emotion processing difficulties in children with externalising symptoms may change with development. For example, pre-adolescents with hyperactivity (12 years or older) did not present difficulties in facial emotion processing (Guyer et al., 2007), compared to younger (7- to 12-year-old) children, who did present such difficulties (Corbett & Glidden, 2000; Pelc et al., 2006). Shapiro and colleagues (1993) found difficulties in facial emotion identification and matching tasks in hyperactive children younger than 8 years of age but not in older children. It is not clear whether such developmental effects would generalise to vocal emotional processing. In contrast to accuracy, showing little stability over time, response bias to facial anger showed greater developmental continuity and robust links with behaviour problems over time (Barth & Bastiani, 1997).

The finding that deficits seem to be more pronounced in younger participants with behaviour problems is compatible with developmental accounts of emotion understanding, suggesting that knowledge of basic emotions (i.e. angry, happy, sad) is more salient in day-to-day social interactions in early childhood (Denham, 1998), whereas more complex forms of emotion understanding, such as social emotions (i.e. guilt; embarrassment) and display rules become more relevant in social relationships during late childhood and adolescence (Saarni, 1999; van Beek & Dubas, 2008). A recent meta-analysis of over 70 studies revealed that 'emotion knowledge', defined as emotion understanding from a wide range of non-verbal social cues, was negatively associated with externalising symptoms in early childhood and preadolescence but not in middle childhood (Trentacosta & Fine, 2010). The authors suggested that younger children and adolescents may be more vulnerable to emotion processing difficulties compared to primary school-aged children.

The present study aimed to investigate emotion processing in 4- to 10-year-old children with externalising (i.e. hyperactivity, conduct problems) and internalising symptoms (i.e. emotional problems), in order to examine whether emotion processing difficulties found in preschoolers with behaviour problems in Study 1, would extend to middle childhood. It was predicted that emotion processing difficulties found in preschoolers (Study 1) would be less evident in 4- to 10-year-old children (Study 3). Also, consistent with previous research (Fields, 2008; Friedman et al., 2003; Rapport et al., 2002), the present study predicted that emotion processing difficulties (i.e. lower accuracy) would be present in adults with symptoms of inattention, hyperactivity and anxiety.

4.3.2 Aims

The aims of the present study were as follows:

1. To examine the development of facial and vocal emotion processing in 4- to 10-year-old children

2. To explore associations between emotion processing and psychopathology in children and adults.

4.3.3 Methods

4.3.3.1 Participants

A total of 117 participants from the community were recruited to the study. This was a different sample from that used in Study 1 and Study 2. Eight children failed to complete both tasks and were excluded from the study (age range 3.92-8.58 years, mean age=5.38 years, SD=1.62 years, 5 boys). The final study sample comprised 109 individuals (88 children, 21 adults). Children were divided to four groups: Group 1 (Year R): age range 3.67-5.33 years, mean age=4.46, SD=.44, 11 boys, 12 girls, Group 2 (Year 2/3): age range 6.00-7.42, mean age=6.57, SD=.33, 15 boys, 9 girls, Group 3 (Year 4): age range 7.75-9.17, mean age=8.39, SD=.43, 8 boys, 11 girls, and Group 4 (Year 5/6): age range 9.33-10.75, mean age=10.13, SD=.35, 8 boys, 14 girls. The rationale for the 4 age groups was based on previous developmental literature (see section 4.3.1). Group 5 consisted of adult participants: age range 21.67-45.83, mean age=27.83, SD=5.33, 11 males, 10 females. Power calculations (G*Power software) indicated that in the present study a sample size of 109 individuals can detect an effect size of 0.25 (post-hoc calculation) with an α error probability of .005 (repeated measures ANOVA, for 5 age groups consisting of 4, 6, 8, 10-year-old children and adults). School teachers were asked to recommend for the study children with no hearing or visual impairments, learning difficulties and psychiatric conditions based on school records. Adult participants were a convenience sample of University students.

4.3.3.2 Materials

4.3.3.2.1 Facial expression stimuli

The present study employed face stimuli from the same battery used in Study 1. These stimuli have been used widely in relevant research with children of similar ages as in this study (Durand et al., 2007). A set of 3 (emotions: angry, happy and sad plus one neutral) x 3 (intensity levels: 50%, 75% and 100%) expressions from the same female actress comprised the stimulus material for this study.

4.3.3.2.2 Vocal expression stimuli

A set of 3 (emotion: angry, happy and sad plus one neutral expression) x 3 (intensity: 50%, 75% and 100%) stimuli were used in the present study (see Study 2 for further details). Study 2 selected one item of each emotion and intensity category to use in Study 3. Criteria for stimuli selection were based on a criterion of two units of difference between high and low intensity expressions. Final items considered to express high (75%) levels of emotion had mean agreement from 72 to 77% while those considered to express low (50%) levels of emotion mean percent agreement of 40% (see Table 4.3 and Appendix B). Importantly, the selected items were those that were judged by the participants not only more representative of the emotion but also more 'intense' on a 1-4 point scale. Alongside the emotional expressions, one neutral item with the highest mean agreement (60%) and highest mean intensity rating was selected from Study 2. These items were adopted for this study alongside their full intensity (100%) equivalents[2], in terms of actor, from the same battery (Maurage et al., 2007) to allow comparisons with full intensity stimuli. The 100% intensity stimuli have been previously validated in adults (Maurage et al., 2007).

Table 4. 3. *Mean agreement (%) in adults and children on emotion expressed for the selected vocal stimuli validated in Study 2.*

Item No	Vocal Expression	Adults	Children	Total
23	Angry-75%	86.4	66.7	77.5
12	Angry-50%	40.9	38.9	40.0
7	Happy-75%	81.8	61.1	72.5
5	Happy-50%	40.9	38.9	40.0
4	Sad-75%	86.4	55.6	72.5
29	Sad-50%	44.5	33.3	40.0
1	Neutral	77.3	38.9	60.0

[2] The full intensity (100%) equivalents for the selected items were items No 112Ha16, 22 An22 and 186Sa25 for angry, happy and sad respectively, see Maurage et al., 2007 for details.

4.3.3.3 Task Design

Children took part in two tasks i) a facial emotional expression and ii) a vocal emotional expression identification task with tasks counterbalanced in order across participants. The experiment consisted of a four choice emotion identification task with four response options (angry, happy, sad and neutral/'ok') across two modalities and three intensities (i.e. 50%, 75% and 100%). Each task (face/voice) consisted of 120 experimental trials (9 trials per emotion x intensity condition plus a neutral expression) presented in two blocks of 60 trials each. There was a 5-minute rest break in between the two blocks. Children participated in 10 practice trials identical to those in the experimental trials (one per emotion x intensity condition, plus a neutral) at the beginning of each task. Children were given clear instructions about the response options and did not receive feedback about their performance accuracy. Children took part in the second task (i.e. either face or voice) after completion of the first task. The following instructions were given to the children verbally before the practice block of each task:

'You are going to see some faces/hear some voices. You need to identify the emotion in the face/voice and press one of the four keyboard buttons with the labels 'angry', 'happy', 'sad' or 'okay' to indicate your response. [For 4-year-olds: 'You need to tell me if the face/voice is angry, happy, sad or okay']. Try to respond as accurately as you can. In between each face/voice you will see a small cross on the centre of the screen. Please look at this throughout the task. If you don't understand the instructions, ask the experimenter now'.

After checking that the children had understood the instructions, children continued on to the practice trials and the main experimental block. Each trial begun with the presentation of a central fixation cross (500 ms) followed by the presentation of the stimulus (face: 1000 ms, voice: 700 ms duration) followed by a blank screen until the participants gave a verbal response and a 1000 ms inter-trial interval. As children in this study were older compared to Study 1, duration of the facial and vocal stimuli was shorter. Facial expressions were displayed on a computer monitor. Vocal expressions were presented via speakers. Stimuli presentation was randomised across participants. As not all 4-year-olds in this study were competent readers of emotion words on response buttons, immediately after presentation of the stimulus, the experimenter read-out to the child, in counterbalanced order across trials, four response options (is the face/voice angry, happy, sad or okay?). This was facilitated by the use of script cards (6 possible combinations of emotion words x 4 emotions leading to a number of 24 script cards). Administration was identical for 6, 8, 10-year-old children and adults. Participants' responses were logged into the computer via Inquisit Software v.2 (Millisecond.com).

4.3.3.4 Child and Adult Measures of Psychopathology

4.3.3.4.1 Teacher-rated measures of child behaviour

The Strengths and Difficulties Questionnaire – SDQ teacher form (Goodman, 1997) was used for the assessment of behaviour problems in children (see section 3.3.5.1.1). For the purposes of the present study three sub-scales (15 items) were used measuring hyperactivity conduct problems and emotional problems. Internal consistency of the teacher forms are reported to be good with Cronbach's alphas .77, .76, and .89 for conduct, emotional, and hyperactivity scales respectively. In addition, parent-teacher correlation coefficients are .65, .41 and .54 for conduct, emotional and hyperactivity symptoms respectively (Goodman, 1997, 2001). In the present study internal consistency was good with a Cronbach's alpha=.74, .68 and .81 for the conduct, emotional and hyperactivity scales respectively and .83 for the whole scale.

4.3.3.4.2 Adult symptoms of inattention and hyperactivity

The Attention Deficit Hyperactivity Disorder -Current Behaviour Scale- ADHD-CBS (Barkley & Murphy, 1998) was used for a self-report measure of symptoms of inattention and hyperactivity in adults (see section 3.3.5.2.1). Internal consistency for the present study was good with Cronbach's alpha=.71 for the scale.

4.3.3.4.3 Adult symptoms of anxiety

The State Trait Anxiety Inventory (STAI) (Spielberger, 1983) was used as a self-report measure of trait and state anxiety in adults. This consists of two 20-item scales, one measuring current level of anxiety (state) and the other measuring the usual level of anxiety (trait). The trait anxiety scale uses a 4-point Likert-type frequency scale: (1) almost never, (2) sometimes, (3) often and (4) almost always. Representative trait anxiety items included 'I worry too much about something that doesn't really matter' and 'I am content'. The state anxiety scale consists of a 4-Likert-type intensity scale: (1) not at all, (2) somewhat, (3) moderately so and (4) very much so. Representative state anxiety items included: 'I feel tense' and 'I feel nervous'. For both scales higher scores indicate higher levels of anxiety. The STAI scales are designed to assess unidimensional constructs and as such a single global score can be derived by summing the scores on all items (maximum score= 80). In this study a mean score was used by dividing the total score by the number of items in each scale. Reported internal consistency for the STAI is good, with

Cronbach’s alphas of .90 for the state anxiety scale and .92 for the trait anxiety scale (Spielberger & Vagg, 1984). The Cronbach’s alpha for this study was .91 for both scales.

4.3.3.5 Procedure

Ethical approval for this study was obtained from the School of Psychology Ethics committee and the University of Southampton Research Governance. Children were recruited from primary schools in the Southampton area. Schools consenting to take part in the study forwarded information about the study to parents of children. Parents’ written consent was obtained via the school. The teachers also provided written consent for participation. Following parent and teacher consent, the researcher provided information about the study to the children and child assent was obtained. Adult participants were recruited via posters at the University of Southampton. Adults gave written informed consent prior to participation. Children took part in the study in a quiet room of their school and adults at the University. A summary of the study results was sent to the primary schools participating in this study and the adult participants after completion of the study.

4.3.4 Results

4.3.4.1 Performance

Following data processing (see section 3.4) initial analyses aimed to explore the general performance levels of discrimination accuracy and response bias to facial and vocal expressions within each age group and to examine between groups comparisons prior to exploring associations with psychopathology.

4.3.4.1.1 Facial Emotion Processing

4.3.4.1.1.1 Initial data treatment for discrimination accuracy and response bias

Kolmogorov-Smirnov tests were conducted for the accuracy and bias measures within each age group. Accuracy values did not differ significantly from normality ($p > .05$) except for angry and happy 100% expressions in 6-year-olds, 8-year-olds and 10-year-olds (z from 1.38 to 1.71, p values from .021 to .043) and happy 75% expressions in 6-year-olds ($z=1.53$, $p=.018$) and adults ($z=1.48$, $p=.024$). All values of response bias did not differ significantly from normality ($p > .05$). Because the majority of accuracy and all the bias values did not differ significantly from normality, values of accuracy were not log transformed for subsequent analyses.

4.3.4.1.1.2 Discrimination Accuracy

4.3.4.1.1.2.1 Overall Performance

Analyses tested whether participants performed above chance levels as for discrimination accuracy. One sample t-tests were conducted for each cell against chance (a score of zero). Values of discrimination accuracy for facial expressions per emotion and intensity were entered in analyses. Results indicated that accuracy was significantly different from chance ($p<.001$) across all intensities and emotion types.

4.3.4.1.1.2.2 The effect of emotion, intensity and age on discrimination accuracy for facial expressions

The effect of emotion type, intensity and age on recognition accuracy for facial expressions was examined. Accuracy (Pr) scores were entered in a repeated measures ANOVA with 3 emotion (Angry, Happy, Sad) x 3 intensity (Low-50%, Moderate-75%, High-100%) as within-subject factors and age as a between-subject factor.

Results revealed a significant difference in accuracy between age groups (F (4, 104) = 15.41, p<.001, η^2_p = .37). Post-hoc pairwise comparisons showed that preschoolers presented significantly lower accuracy than all other age groups. Adults presented significantly higher accuracy compared to 4, 6 and 8-year-olds but they were not significantly different from 10-year-olds. There was also a main effect of emotion on accuracy (F (2, 208) = 64.64, p< .001, η^2_p = .38). Accuracy for angry (M=.73, SE=.01) and happy (M=.76, SE=.01) faces was significantly higher than for sad faces (M=.55, SE=.01, all ps<.001). Results also showed a significant main effect of intensity on accuracy (F (2, 208) = 187.31, p<.001, η^2_p =.64). Participants were significantly more accurate in discriminating high-100% (M=.76, SE=.01) compared to moderate-75% (M=.71, SE=.01), moderate compared to low-50% (M=.56, SE=.01) and high compared to low intensity expressions (p<.001). There was no significant emotion x age interaction effect on accuracy (F (8, 208) = 1.39, p= .201, η^2_p = .05).

Results showed a significant intensity x age interaction effect on accuracy (F (8,198) =2.95, p=.009, η^2_p =.10). For each emotion x intensity condition, the three emotions were averaged and then by one-way ANOVA the effect of intensity on accuracy for each age group separately was examined. Results showed a significant difference between groups for accuracy for low-50% (F (4,108) =10.93, p=.001), moderate-75% (F (4,108) =14.07, p=.001) and high-100% (F (4,108) =16.17, p<.001) intensity faces. Post-hoc comparisons showed that preschoolers were significantly less accurate than other groups in discriminating moderate-75% and high-100% intensity faces, for low-50% intensity faces, however, they did not differ from 8-year-olds. No significant differences were found in accuracy for all three intensity levels between 6 and 8-year-olds, between 6 and 10-year-olds and between 10-year-olds and adults (p<.05). In addition, 8-year-olds did not differ from 10-year-olds in accuracy for low-50% and moderate-75% intensity faces. Results are presented graphically in Figure 4.1.

Emotion x intensity interaction effect on accuracy

There was also a significant emotion x intensity interaction effect on accuracy (*F* (4, 416) =5.10, p=.002, η^2_p =.47). Further post-hoc analyses examined the effect of emotion at each separate level of intensity via one-way ANOVAs. Results showed a significant effect of emotion on accuracy for 50% intensity faces (*F* (2, 116) =26.00, p<.001, η^2_p =.19). Separate paired sample t-tests showed that participants were more accurate for happy compared to angry [t (108) = 2.67, p=.008], happy compared to sad [t (108) = 6.82, p<.001] and angry compared to sad 50% [t (108) = 4.86, p<.001] intensity. Also, results indicated that emotion had a significant effect on accuracy for 75% intensity, (*F* (2, 116) =66.90, p<.001, η^2_p =.38). Participants were more accurate for happy compared to sad [t (108) = 10.27, p<.001], angry compared to sad [t (108) = 9.27, p<.001] but there was no significant difference in accuracy between happy and angry [t (108) = .96, p=.338] at 75% intensity. Finally, results indicated that emotion had a significant effect on accuracy for 100% intensity (*F* (2, 116) =56.62, p<.001, η^2_p =.34). Accuracy was higher for angry compared to sad [t (108) = 8.90, p<.001] and happy compared to sad [t (108) = 9.60, p<.001] but there was no significant difference in accuracy between angry and happy [t (108) = .63, p=.530] at 100% intensity.

A second set of analyses examined the effect of intensity at each separate level of emotion via one-way ANOVAs. Results showed intensity had a significant effect on accurate recognition of angry faces (*F* (2, 216) =91.28, p<.001, η^2_p =.46). Participants were more accurate for 100% compared to 50% [t (108) = -10.64, p<.001], 100% compared to 75% [t (108) = -4.96, p<.001] and 75% compared to 50% intensity [t (108) = -8.97, p<.001] angry faces. Results also showed a significant difference between intensities for happy faces (*F* (2,216) =39.72, p<.001, η^2_p =.27). Accuracy was higher for 100% compared to 50% [t (108) = -6.74, p<.001], 75% compared to 50% [t (108) = -6.78, p<.001] but not for 100% compared to 75% [t (108) = -1.38, p<.001] happy faces. Finally, results showed intensity had a significant effect on accurate recognition of sad faces (*F* (2, 216) =61.75, p<.001, η^2_p =.35). Participants were more accurate for 100% compared to 50% [t (108) = -9.64, p<.001], 100% compared to 75% [t (108) = -4.31, p<.001] and 75% compared to 50% intensity [t (108) = -7.28, p<.001] sad faces.

Emotion x intensity x age interaction effect on accuracy

In addition, results revealed a significant emotion x intensity x age interaction effect on accuracy (*F* (16,416) =2.69, p=.001, η^2_p=.09). To break down this interaction effect, simple contrasts were performed. A first set of contrasts compared angry to sad and happy to sad while comparing 50% to 100% and 75% to 100% intensity. Results showed a significant emotion x intensity x age contrast between angry and sad when comparing 50% to 100% (*F* (4,104) =4.42, p=.002, η^2_p=.14) and 75% to 100% (*F* (4,104) =5.35, p=.001, η^2_p=.17) intensity. There was also a significant contrast between happy and sad when comparing 50% to 100% intensity (*F* (4,104) = 4.94, p=.001, η^2_p=.16). A two-way ANOVA was conducted for each age group separately. Simple planned contrasts compared angry to sad and happy to sad while comparing 50% to 100% and 75% to 100% intensity. Preschoolers were significantly more accurate for 100% compared to 50% (*F* (1, 22) =7.41, p=.012, η^2_p =. 25) and for 100% compared to 75% (*F* (1, 22) =6.80, p=.02, η^2_p =.23) for angry expressions compared to sad. Eight-year-olds were significantly more accurate for 100% compared to 50% intensity for angry compared to sad (*F* (1, 18) =8.18, p=.010, η^2_p =. 09). In 10-year-olds there was a steeper improvement in accuracy from 75% to 100% intensity for sad compared to angry (*F* (1, 21) =5.25, p=.032, η^2_p =. 20) and happy (*F* (1, 21) =5.35, p=.031, η^2_p =.20) expressions. In adults, there was a significantly smaller difference in accuracy between 50% and 100% (*F* (1, 20) =23.79, p<.001, η^2_p =.54) and between 75% and 100% (*F* (1, 20) =8.82, p=.008, η^2_p =.30) intensity for happy compared to sad. In addition, in adults there was a smaller difference in accuracy between 75% and 100% intensity for angry compared to sad (*F* (1,20)=5.52, p=.029, η^2_p =.21).

A second set of contrasts compared angry to sad and happy to sad while comparing 75% to 50% intensity[3]. Results showed a significant contrast between angry and happy (*F* (3, 82) =3.15, p=.029, η^2_p=.10) and happy and sad (*F* (3, 82) =3.02, p=.034, η^2_p=.10) when comparing 75% to 50% intensity. In 6-year-olds, there was greater improvement in accuracy from 50% to 75% for angry compared to sad faces (*F* (1, 23) =7.88, p=.010, η^2_p =.25). The same pattern of effects was observed in 8-year-olds (*F* (1, 18) =5.22, p=.035, η^2_p =.23). In adults, there was greater improvement in accuracy from 50% to 75% for sad compared to happy faces (*F* (1, 20) =17.27, p<.001, η^2_p =.46). No other difference reached significance (p>.05).

Means and standard deviations for accuracy per group are presented in Table 4.4. Results suggest that a significant improvement in discriminating different levels of intensity in facial expressions occurs after the preschool years.

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[3] There was no significant contrast between angry and happy comparing 50% to 100% (*F* (4,104) =.60, p=.663, η^2_p=.02) and 75% to 100% (*F* (4,104) = .75, p=.562, η^2_p=.02) intensity and no significant contrast between angry and happy comparing 75% to 50% (*F* (4,104) = 1.24, p=.300, η^2_p=.04) intensity faces.

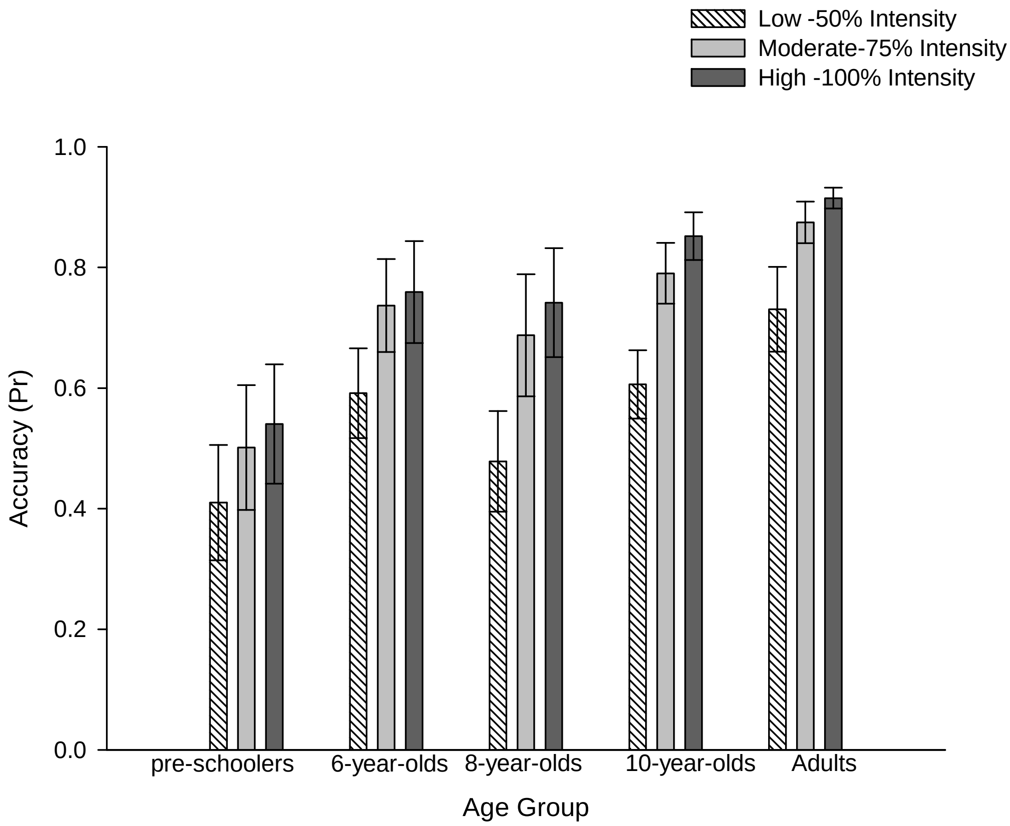


Figure 4. 1. 95% confidence interval bar charts with error bars for mean accuracy (Pr) scores for facial expressions per age group

Table 4. 4. *Mean (SD) of discrimination accuracy for angry, happy and sad facial expressions of varying intensity per age group*

Age Group	Angry			Happy			Sad		
	50%	75%	100%	50%	75%	100%	50%	75%	100%
preschoolers	.39(.29)	.50(.32)	.60(.33)	.52(.24)	.63(.27)	.65(.24)	.31(.28)	.36(.28)	.36(.28)
6-year-olds	.56(.26)	.81(.19)	.81(.21)	.70(.24)	.82(.18)	.81(.19)	.49(.25)	.57(.25)	.64(.24)
8-year-olds	.51(.26)	.79(.22)	.87(.16)	.52(.34)	.73(.29)	.78(.27)	.38(.24)	.53(.25)	.56(.25)
10-year-olds	.68(.22)	.88(.09)	.93(.03)	.68(.26)	.88(.12)	.90(.08)	.44(.21)	.59(.22)	.71(.18)
Adults	.74(.21)	.91(.04)	.93(.02)	.87(.09)	.91(.06)	.91(.04)	.57(.26)	.79(.17)	.89(.05)

Note 1: Accuracy values range: -1≈worse than chance, 0≈chance, 1≈better than chance. Note 2: $t\ (21) > 5.27$, $ps<.001$ for all emotion x intensity conditions

4.3.4.1.1.3 Response Bias

4.3.4.1.1.3.1 The effect of emotion and age on response bias to facial expressions

Further analyses examined the effect of emotion and age on response bias to facial expressions. Response bias (Br) scores were entered in a repeated measures ANOVA with emotion (Angry, Happy, Sad) as within-subject factor and age as between-subject factor.

Results revealed significant differences in bias between age groups (F (4, 104) = 5.55, p<.001, η^2_p = .17). Pair-wise comparisons showed that preschoolers presented significantly higher response bias (M=.25, SE=.01) compared to 8-year-olds (M=.17, SE=.01, p=.029), 10-year-olds (M=.15, SE=.01, p<.001) and adults (M=.16, SE=.01, p=.003). No other difference reached significance (p>.05). Results also showed a significant difference in bias between emotions (F (2, 208) = 5.09, p=.007, η^2_p= .47). Participants presented higher response bias to sad (M=.22, SE=.01) followed by happy (M=.18, SE=.01) and angry (M=.16, SE=.01), suggesting a higher tendency for participants to attribute sadness followed by happiness and then anger to facial expressions. Pair-wise comparisons revealed a significant difference in bias between angry and sad (M=-.07, p=.007). No other difference reached significance (p>.05). Results showed no age x emotion interaction effect on response bias to facial expressions (F (8,208) =.66, p=.73, η^2_p = .02). Means and standard deviations for response bias per age group are presented in Table 4.5. Results are presented graphically in Figure 4.2.

Table 4. 5. *Mean (SD) of response bias to facial expressions per age group and emotion.*

	Facial Emotional Expression		
Age group	Angry	Happy	Sad
preschoolers	.18(.16)	.28(.16)	.27(.19)
6-year-olds	.15(.10)	.21(.19)	.24(.18)
8-year-olds	.14(.10)	.15(.14)	.22(.19)
10-year-olds	.13(.11)	.12(.10)	.21(.17)
Adults	.15(.11)	.14(.10)	.17(.16)

Note: Response bias values range from 0 -1. Absence of bias ≈ 0, Presence of bias ≈ 1

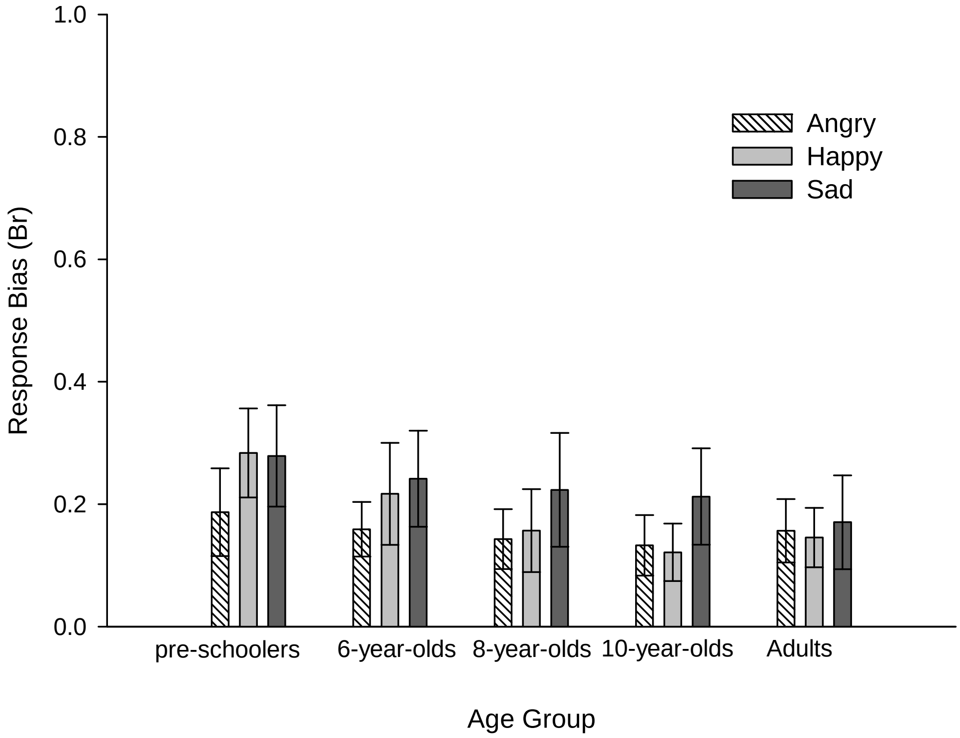


Figure 4. 2. 95% confidence interval bar charts with error bars for mean response bias (Br) scores for facial emotional expressions per age group

4.3.4.1.1.3.2 Correct classifications and misattribution patterns

Misattribution patterns of emotional and neutral facial expressions in each age group separately were examined. Misattribution patterns are presented in Appendix B. Preschoolers presented the highest number of misattributions of facial expressions, although this pattern was not consistent across emotions. Adults presented the lowest number of misattributions. There was a general tendency for participants to classify emotional expressions, especially of lower intensity, as neutral. There was also a tendency for children to classify neutral expressions as sad.

4.3.4.1.2 Vocal Emotion Processing

4.3.4.1.2.1 Initial data treatment for discrimination accuracy and response bias

Kolmogorov-Smirnov tests were conducted for the accuracy and bias measures within each age group. Accuracy values did not differ significantly from normality ($p>.05$) except for accuracy for angry 75% ($z=1.58$, $p=.014$) and 100% ($z=1.50$, $p=.022$) expressions in adults. All values of response bias did not differ significantly from normality ($p>.05$). Because the majority of accuracy and all the bias values did not differ significantly from normality, values of accuracy were not log transformed for subsequent analyses.

4.3.4.1.2.2 Discrimination Accuracy

4.3.4.1.2.2.1 Overall performance

One sample t-tests were conducted for each cell against chance (a score of zero) to examine whether participants performed above chance levels as for discrimination accuracy for voices. Results showed that accuracy was significantly different from chance ($p<.05$ and $p<.001$) for all age groups. However, accuracy was not significantly different from chance for angry and sad expressions of 50% intensity in preschoolers ($p<.08$) and for happy expressions of 50% intensity in 8-year-olds (see Table 4.7).

4.3.4.1.2.2.2 The effect of emotion, intensity and age on discrimination accuracy for vocal expressions

The effect of emotion, intensity and age on accuracy for vocal expressions was examined. Accuracy scores were entered in repeated measures ANOVA with 3 emotion (Angry, Happy, Sad) x 3 intensity (Low-50%, Moderate-75%, High-100%) as within-subject factors, and age as the between-subject factor. Because preschoolers' performance accuracy was not significantly different from chance for two emotions (angry, sad), preschoolers were not included in these analyses.

Results revealed age to have a significant main effect on accuracy (F (3, 82) =10.54, p<.001, η^2_p =.27). Post-hoc pairwise comparisons showed that adults were significantly more accurate compared to all child groups in discriminating vocal expressions (p<.05). However, 6-year-olds did not differ significantly from 8 and 10-year-olds in their accuracy to discriminate vocal emotional expressions. Also, 8-year-olds did not differ significantly from 10-year-olds. Emotion had a significant main effect on accuracy for vocal expressions (F (2,164) = 47.37 p<.001, η^2_p =.36). Post-hoc tests showed that participants were more accurate to discriminate angry (M=.61, SE=.02) compared to happy (M=.46, SE=.02) and sad (M=.37, SE=.02) voices and also happy compared to sad voices (p<.001). A significant difference in accuracy between intensities was also found (F (2,164) =226.46, p<.001, η^2_p =.73). Participants were significantly more accurate in discriminating high-100% (M=.60, SE=.02) compared to low-50% (M=.26, SE=.02) and moderate-75% (M=.58, SE=.02) compared to low-50% intensity expressions (p<.001) but there was no significant difference in accuracy between high and moderate intensity.

Results showed no significant emotion x age (F (6, 164) = 1.69, p=.12, η^2_p =.06), intensity x age (F (6, 164) = 1.20, p=.315, η^2_p =.04) or emotion x intensity x age (F (2, 328) =1.70, p=.065, η^2_p=.06) interaction effect on accuracy for vocal expressions.

There was a significant emotion x intensity interaction effect on accuracy for vocal expressions (F (4,328) =78.88, p<.001, η^2_p=.49). Further post-hoc analyses on the emotion x intensity interaction effect were conducted. A first set of analyses examined the effect of emotion at each separate level of intensity via one-way ANOVAs. Results showed emotion had a significant main effect on accuracy for 50% intensity voices (F (2, 170) =26.36, p<.001, η^2_p =.24). Separate paired sample t-tests showed that participants were more accurate for angry compared to happy [t (85) = 5.70, p<.001] and sad compared to happy [t (85) = 7.86, p<.001] but there was no significant difference in accuracy between angry and sad [t (85) = -1.18, p=.241] 50% intensity voices. Results also showed a significant effect of emotion on accuracy for 75% intensity voices (F (2, 170) =74.56, p<.001, η^2_p =.47).

Paired comparisons showed that participants were more accurate in discriminating angry compared to happy [t (85) = 6.62, p<.001], angry compared to sad [t (85) = 11.04, p<.001] and happy compared to sad [t (85) = 6.38, p<.001] 75% intensity voices. Finally, results showed emotion had a significant main effect on accuracy for 100% intensity voices (F (2, 170) =81.10, p<.001, η^2_p =.49). Participants were more accurate for angry compared to happy [t (85) = 2.94, p=.004], angry compared to sad [t (85) = 10.50, p<.001] and happy compared to sad [t (85) = 9.79, p<.001] 100% intensity expressions.

A second set of analyses examined the effect of intensity at each separate level of emotion via one-way ANOVA. Results showed a significant difference between intensities in the discrimination of angry voices (F (2, 170) =138.37, p<.001, η^2_p =.62). Participants were more accurate at 100% compared to 50% [t (85) = 11.67, p<.001] and 75% compared to 50% [t (85) = 12.45, p<.001] but there was no significant diference in accuracy between 100% and 75% [t (85) = .97, p=.334] intensity angry voices. Also, results showed intensitiy had a significant a main effect on accuracy for happy voices (F (2,170) =195.70, p<.001, η^2_p =.69). Participants were more accurate for 100% compared to 50% [t (85) = 15.60, p<.001], 100% compared to 75% [t (85) = 5.33, p<.001] and 75% compared to 50% [t (85) = 13.42, p<.001] intensity happy voices. Finally, results showed no significant effect of intensity on accuracy for sad voices (F (2, 170) =1.59, p=.209, η^2_p =.02).

In summary, the results suggest that emotion prosody perception reaches adult-like levels of performance by late childhood. Means and standard deviations for discrimination accuracy per age group are presented in Table 4.6.

Table 4. 6. *Mean (SD) of discrimination accuracy for angry, happy and sad vocal expressions of varying intensity per age group.*

	Angry			Happy			Sad		
Age Group	50%	75%	100%	50%	75%	100%	50%	75%	100%
preschoolers	.04(.12)	.20(.28)	.21(.30)	.08(.13)	.09(.21)	.14(.24)	.08(.21)	.11(.20)	.11(.16)
6-year-old	.25(.29)	.65(.34)	.64(.37)	.09(.17)	.46(.37)	.56(.38)	.29(.27)	.28(.30)	.26(.31)
8-year-old	.14(.21)	.70(.27)	.68(.30)	.05(.14)	.44(.36)	.54(.39)	.26(.24)	.30(.29)	.24(.24)
10-year-old	.32(.33)	.83(.16)	.81(.22)	.13(.19)	.66(.31)	.70(.31)	.30(.26)	.33(.33)	.28(.29)
Adults	.52(.35)	.90(.12)	.90(.11)	.18(.22)	.79(.16)	.89(.07)	.58(.21)	.63(.23)	.63(.25)

Note: Accuracy values range: -1≈worse than chance, 0 ≈ chance, 1≈better than chance.

Table 4. 7. *t scores (p values) of discrimination accuracy for vocal expressions for each cell against chance (a score of zero) by emotion, intensity and age.*

	Angry			Happy			Sad		
Age Group	50%	75%	100%	50%	75%	100%	50%	75%	100%
Preschooler t(p)	1.80(p=.085)	3.32 (p<.01)	3.26 (p<.01)	2.92 (p<.01)	2.16 (p<.05)	2.89 (p<.01)	1.77 (p=.090)	2.63 (p<.05)	3.32 (p<.01)
6-year-old t (p)	4.20(p<.001)	9.26(p<.001)	8.41(p<.001)	2.69(p<.05)	6.20(p<.001)	7.29(p<.001)	5.24(p<.001)	4.51(p<.001)	4.04(p<.001)
8-year old t(p)	2.87 (p<.01)	11.14(p<.001)	9.82(p<.001)	1.59(p=.128)	5.40(p<.001)	6.05(p<.001)	4.68(p<.001)	4.42(p<.001)	4.45(p<.001)
10-year-old t(p)	4.54(p<.001)	24.11(p<.001)	16.82(p<.001)	3.34 (p<.01)	9.95(p<.001)	10.52(p<.001)	5.24(p<.001)	4.73(p<.001)	4.52(p<.001)
Adults t (p)	6.81(p<.001)	32.33(p<.001)	36.20(p<.001)	3.80(p=.001)	21.87(p<.001)	51.36(p<.001)	12.29(p<.001)	12.58(p<.001)	11.49(p<.001)

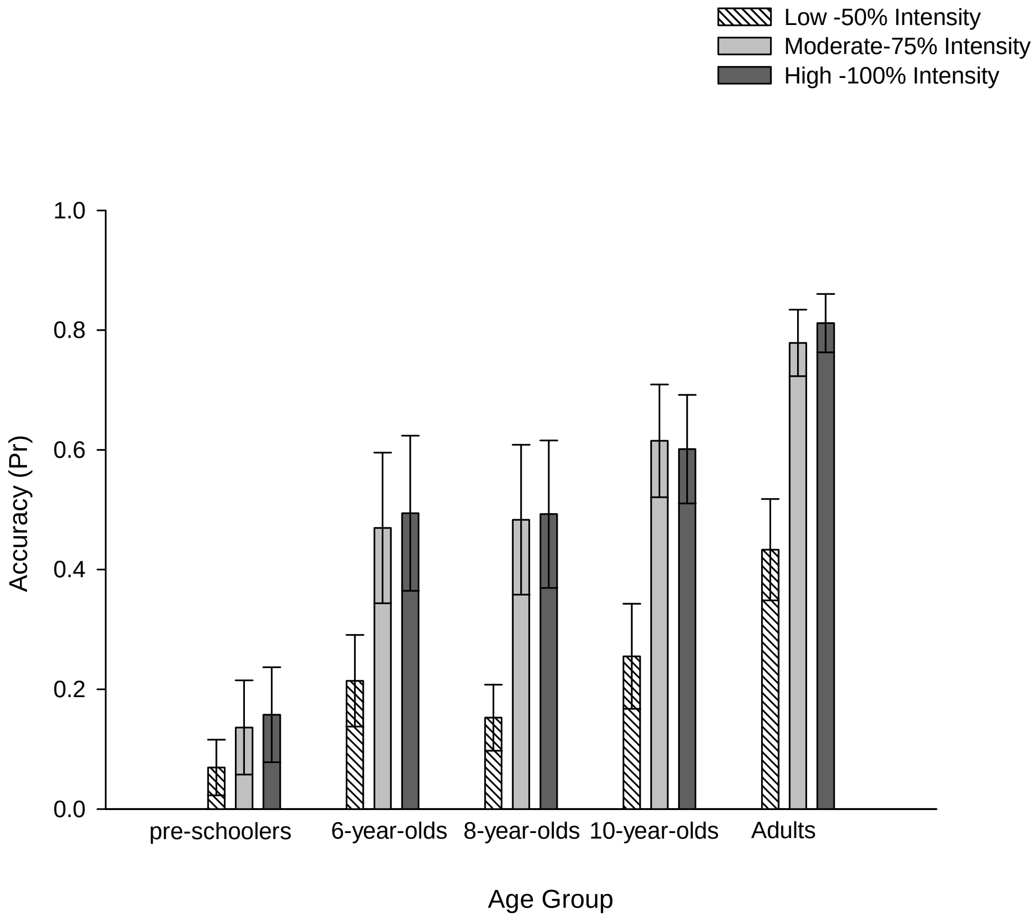


Figure 4. 3. 95% confidence interval bar charts with error bars for mean accuracy (Pr) scores for vocal emotional expressions per age group

4.3.4.1.2.3. Response Bias

4.3.4.1.2.3.1 The effect of emotion and age on response bias to vocal expressions

The effect of emotion and age on response bias to vocal expressions was examined. Response bias scores were entered in a repeated measures ANOVA with emotion (Angry, Happy and Sad) as within-subject factors and age as the between-subject factor. As above, preschoolers were not included in these analyses.

Results showed a significant difference in bias between age groups, (F (3, 82) =5.09, p=.003, η^2_p =.16). Pair-wise comparisons indicated that 6-year-olds (M=.22, SE=.01) showed higher response bias compared to 10-year-olds (M=.16, SE=.01, p=.007) and adults (M=.16, SE=.01, p=.011). Results also revealed that emotion had a significant main effect on response bias (F (2,164) =31.37, p<.001, η^2_p =.27). Participants presented higher response bias to sad (M=.28, SE=.01) followed by bias to angry (M=.16, SE=.01) and happy (M=.10, SE=.01), suggesting a higher tendency to attribute sadness followed by anger and happiness to vocal expressions. There was a significant difference in bias between angry and sad as well as happy and sad (p<.001) and between angry and happy (p=.011). Results showed no significant emotion x age interaction effect on response bias to vocal expressions (F (6,164) =.82, p=.535, η^2_p =.03). Means and standard deviations for response bias per age group and emotion are presented in Table 4.8.

Table 4. 8. *Mean (SD) of response bias to vocal expressions per age group and emotion*

Age group	Vocal Emotional Expression		
	Angry	Happy	Sad
preschoolers	.22(.16)	.28(.16)	.28(.13)
6-year-olds	.18(.14)	.14(.10)	.34(.16)
8-year-olds	.17(.15)	.12(.11)	.28(.17)
10-year-olds	.12(.09)	.11(.12)	.23(.07)
Adults	.16(.18)	.05(.06)	.24(.17)

Note: Response bias values range from 0 -1. Absence of bias ≈ 0, Presence of bias ≈ 1.

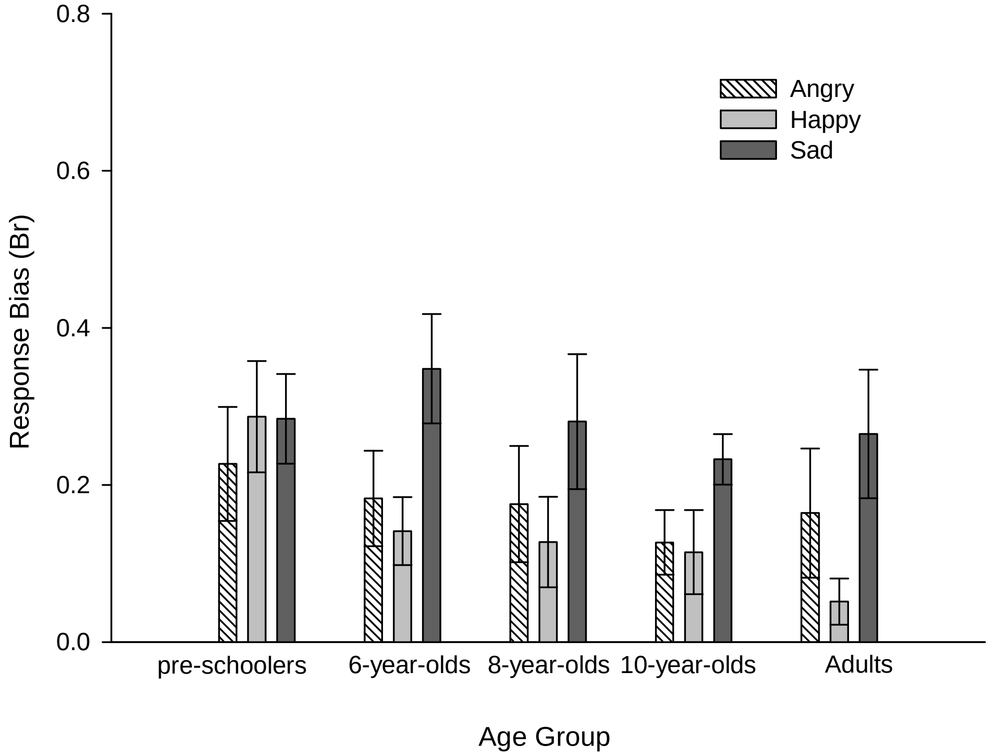


Figure 4. 4. 95% confidence interval bar charts with error bars for mean response bias (Br) scores for vocal emotional expressions per age group

4.3.4.1.2.3.2 Correct classifications and misattribution patterns

Correct classifications and misattribution patterns of vocal expressions for each age group were examined. Misattribution patterns are presented in Appendix B. Visual inspection of these tables shows that preschoolers presented the highest number of misattributions of vocal expressions. There was a general tendency in preschoolers to confuse happy and sad voices. There was also a general tendency for older children and adults to confuse neutral and sad voices. Adults presented the lowest number of misattributions as with facial expressions.

4.3.4.1.3 Intercorrelations among Accuracy and Bias for Faces and Voices

Subsequent analyses aimed to examine the relationship between the two modalities (facial, vocal) regarding discrimination accuracy and response bias. Partial Pearson's correlations in the whole sample controlling for age, examined associations between discrimination accuracy (Pr) and response bias (Br) to facial and vocal expressions. Results showed that discrimination accuracy for facial and vocal expressions were strongly positively associated. Also, there was a strong positive correlation between response bias to facial and vocal expressions. For vocal expressions, bias was negatively associated with discrimination accuracy. For facial expressions, response bias was also negatively associated with discrimination accuracy, although this relationship did not reach significance. Results are summarised in Table 4.9.

The above association patterns were also present within each age group. In preschoolers, accuracy for faces and voices was strongly positively associated ($r=.55$, $p=.007$) as was bias for facial and vocal expressions ($r=.49$, $p=.017$). In 6-year-olds, the same pattern of associations was observed. In 8-year-olds and 10-year-olds associations between accuracy for facial and vocal expressions did not reach significance ($ps >.13$) although they were still in the same (positive) direction as in younger children. Finally, in adults accuracy for faces and voices was positively associated ($r=.52$, $p=.015$) and there was also a tendency for bias to faces and voices to be positively associated ($r=.41$, $p=.062$).

Table 4. 9. *Partial Pearson's correlations (p value) among discrimination accuracy and response bias to facial and vocal expressions in the whole sample controlling for age*

	Pr face	Pr voice	Br face	Br voice
Pr face				
Pr voice	**.65(.001)**			
Br face	-.11(.256)	**-.22(.023)**		
Br voice	-.12(.196)	**-.27(.005)**	**.49(.001)**	**-**

Note: Pr=Discrimination accuracy, Br=Response Bias

4.3.4.2 Psychopathology

4.3.4.2.1 Sample Characteristics

This study identified children and adults from the community with a range of different levels of symptoms. The proportion of participants in the atypical range for symptoms was also explored using the recommended cut-off points (see section 4.3.3.3). Age was not significantly associated with child hyperactivity, conduct problems, emotional problems or adult symptoms ($p>.05$). Table 4.10 displays the means and standard deviations of symptoms and percent of participants who fell in the atypical range per age group.

4.3.4.2.2 Intercorrelations among the psychopathology measures

Further analyses examined whether psychopathology measures were significantly associated with each other. Results showed that in the child sample (N=88), hyperactivity was significantly associated with conduct problems ($r=.63$, $p<.001$) and emotional problems ($r=.26$, $p=.013$). Conduct and emotional problems were also significantly associated ($r=.23$, $p=.034$). In adults, state and trait anxiety were strongly intercorrelated ($r=.88$, $p<.001$), however, inattention and hyperactivity were not. There was no significant difference in the level of symptoms between the child age groups (F (2,166) =.28, p=.76, η^2_p =.003). Direct comparisons as for symptoms between the child and adult groups were not conducted because of the different measures of symptoms for children and adults.

4.3.4.2.3 Data Reduction-Psychopathology

Consistent with Study 1, because child hyperactivity and conduct problems were strongly associated (see above), child hyperactivity and conduct problems were factor analysed through principal component analyses (PCA), based on eigen values greater than 1. The scree plot indicated one factor to be extracted accounting for 81.75% of the total variance. This factor was named ‘Externalising’ because it comprises of items representing externalising symptoms. The eigenvalue for this factor was 1.63. The factor loadings for both hyperactivity and conduct problems were .904. Emotional problems were named ‘Internalising’ in subsequent analyses. Similarly, adult state and trait anxiety were factor analysed, giving rise to a factor named ‘Internalising’ with eigen value of 1.50, accounting for the 74.97% of the total variance. The factor loadings for state and trait anxiety were .866. Adult hyperactivity and inattention were not factor analysed because the two measures were not intercorrelated.

Table 4. 10. *Means (SD) of symptoms in children and adults and percent of participants in the atypical range for symptoms per age group.*

	Conduct Problems		Emotional Problems		Hyperactivity		Inattentive	Stait Anxiety	Trait Anxiety
Age group	Mean (SD)	% atypical	Mean (SD)	% atypical	Mean (SD)	% atypical	Mean (SD)	Mean (SD)	Mean (SD)
preschoolers	1.69(1.79)	30.4%	.86(.86)	0	3.69(2.83)	21.7%	-	-	-
6-year-olds	.62(1.43)	8.3%	1.00(1.35)	0	2.20(2.73)	12.5%	-	-	-
8-year-olds	1.05(1.71)	10.5%	2.10(1.88)	26.3%	3.05(3.17)	21.1%	-	-	-
10-year-olds	1.31(1.88)	22.7%	1.95(2.13)	9.1%	2.95(3.38)	27.3%	-	-	-
Total Children	1.17(1.73)	18.2%	1.31(1.65)	8%	2.96(2.04)	20.5%	-	-	-
Adults	-	-	-	-	4.28(1.90)	-	4.71(2.07)*	1.66(.41)	1.94(.48)

Note: Child: conduct, emotional problems and hyperactivity (SDQ). Adult: hyperactivity and inattention (ADHD-CBS), Stait/Trait Anxiety (STAI). * 5.5% of adults fell in the atypical range for inattentive symptoms. No cut-offs are available for STAI. A cut-off point of ‘some’ needs was used for SDQ, see methods.

4.3.4.2.4 Emotion Processing and Child Psychopathology

Partial Pearson's correlations were conducted between psychopathology and accuracy and bias. Analyses were performed in the whole sample of children controlling for child age because this was more powerful for the purposes of the present study. Pearson's correlations controlled for child age in the child sample because of the wide age range of children (4-10 years). Analyses did not control for child gender because there were no gender effects on accuracy or bias.

For accuracy, separate analyses were conducted for each emotion x intensity condition. In contrast to Study 1 showing no intensity effects on accuracy, in the present study there were strong intensity effects on accuracy. For this reason, intensities were not collapsed per emotion for the accuracy (Pr) scores. The factors 'Externalising' and 'Internalising' were entered in analyses because running the correlations for hyperactivity and conduct problems separately did not change the results (see Appendix B).

Results showed that externalising symptoms were marginally negatively associated with accuracy for angry facial expressions of low intensity. Internalising symptoms were negatively associated with accuracy for sad facial expressions of high intensity (see Table 4.11). When a Bonferroni correction was applied with an alpha level of .05/36=.001 adopted, the above associations did not remain significant. In the bias analyses, results showed that externalising symptoms were negatively associated with response bias to sad vocal expressions which suggests that children with externalising symptoms were less likely to attribute sadness to vocal expressions (see Table 4.12). When a Bonferroni correction was applied with an alpha level of .05/12=.004 adopted, the above associations did not remain significant.

Table 4. 11. *Partial Pearson's correlations (p values) between discrimination accuracy and child symptoms controlling for child age in the whole sample (N=88)*

Accuracy	Child Psychopathology Externalising	Internalising
Face		
Angry 50%	**-.21(.050)**	-.05(.647)
Angry 75%	-.14(.190)	-.04(.688)
Angry 100%	-.11(.290)	.02(.835)
Happy 50%	.04(.706)	-.06(.537)
Happy 75%	-.10(.355)	-.13(.218)
Happy 100%	-.16(.138)	-.17(.108)
Sad 50%	-.19(.066)	-.12(.286)
Sad 75%	-.13(.220)	-.14(.191)
Sad 100%	-.18(.102)	**-.28(.009)**
Voice		
Angry 50%	.03(.767)	-.03(.797)
Angry 75%	.03(.781)	.03(.763)
Angry 100%	.11(.303)	.05(.663)
Happy 50%	-.03(.793)	-.16(.134)
Happy 75%	-.13(.235)	-.02(.829)
Happy 100%	-.19(.070)	-.01(.895)
Sad 50%	.042(.698)	-.00(.967)
Sad 75%	.01(.912)	-.06(.573)
Sad 100%	-.03(.776)	-.04(.743)

Table 4. 12 *Partial Pearson's correlations (p value) between response bias and child symptoms controlling for child age in the whole sample (N=88)*

Bias	Child Psychopathology Externalising	Internalising
Face		
Angry	-.07(.538)	-.14(.201)
Happy	.19(.083)	.03(.754)
Sad	-.00(.981)	.05(.642)
Voice		
Angry	.10(.344)	-.01(.912)
Happy	-.07(.536)	-.02(.828)
Sad	**-.22(.040)**	-.01(.876)

4.3.4.2.5 Emotion Processing and Adult Psychopathology

Full Pearson's correlations examined the relationship between the emotion processing and adult psychopathology. The factor 'Internalising' was entered in analyses because running the analyses for the individual symptoms separately did not change the results. Adult hyperactivity and inattention were entered in analyses separately because the two measures were not inter-correlated. Results showed that symptoms of hyperactivity in adults were negatively associated with accuracy for angry facial expressions of high (100%) intensity ($r=-.59$, $p=.005$). In bias analyses, results showed that hyperactive symptoms in adults were positively associated with bias to angry facial expressions ($r=.62$, $p=.003$). Also, internalising symptoms were negatively associated with bias to sad vocal expressions. No other associations reached significance (ps >.05). Because the main focus of the study was child rather than adult psychopathology, the results are presented in Appendix B.

4.3.5 Discussion

The first aim of Study 3 was to investigate the development of facial and vocal emotion processing in 4- to 10-year-old children. An adult sample was also included for comparison purposes.

Results from Study 3 supported a developmental progression in the ability to recognise facial emotional expressions and highlight the preschool years as an important period in the development of this ability. This is consistent with Study 1 and earlier research with preschoolers (Boyatzis et al., 1993; Philippot & Feldman, 1990; Russell & Bullock, 1986; Widen & Russell, 2003). Accuracy did not differ between the middle childhood age groups, although some studies have reported a significant increase in accuracy for labelling emotional faces from 6 to 8 years (Vieillard & Guidetti, 2009). Also, 10-year-olds performed as accurately as adults in recognising facial expressions, suggesting that an adult-like pattern of facial emotion recognition begins to emerge in pre-adolescence (10 to 11 years), which is consistent with evidence from recent behavioural (Tonks et al., 2007) and electrophysiological (Batty & Taylor, 2006) investigations.

Consistent with Study 1, overall accuracy was higher for angry facial expressions compared to happy and sad expressions, confirming some developmental consistency in the recognition of anger across modalities from the preschool years to middle childhood. However, earlier work using different methodologies showed that anger (Boyatzis et al., 1993) and sadness (Lenti, Giacobbe, & Pegna, 2000; Philippot & Feldman, 1990) were the most difficult to recognise compared to happiness for preschool and school-aged children. Study 3 did not show a developmental pattern on the recognition of specific emotions from facial expressions. Previous research with Ekman faces found that facial recognition accuracy for happiness and sadness was close to adult levels in 5 and 6-year-olds, but accuracy rates for anger did not reach adult levels until the age of 10 (Durand et al., 2007). Other studies showed a flatter developmental profile for happiness, compared to accuracy for anger which developed particularly from 7-8 to 10 years of age (Vicari et al., 2000). Inconsistency of the findings between Study 3 and previous research may be accounted for by different methodologies (review by Gross & Ballif, 1991). For instance, studies using emotion matching tasks in 4- to 15-year-olds found that accuracy in the recognition of facial expressions increased by 8% per year for sad and by 10% per year for happy but not for angry expressions (Herba et al., 2006).

In addition, Study 3 found increased accuracy for more intense facial expressions and an improvement with age in recognising different intensity levels in facial expressions, consistent with prior developmental research (Herba et al., 2008; Gosselin & Pelissier, 1996). Previous research in 4- to 15-year-olds has demonstrated increased recognition accuracy with higher intensity compared to lower intensity facial expressions (Herba et al., 2006) and a gradual improvement in accuracy with greater intensities (Montirosso et al., 2010). Also, in Study 3, preschoolers were less accurate than all other age groups in recognising moderate and high intensity expressions but they did not differ from 8-year-olds in recognising low (50%) intensity expressions. This finding confirms recent work showing that preschoolers were less accurate compared to older children in recognising facial expressions of varying intensity but they did not differ from 7- to 9-year-olds in recognising low (50%) intensity expressions (Montirosso et al., 2010).

Preschoolers presented a higher response bias to facial emotional expressions when compared to older (8 and 10-year-old) children and adults but there were no effects of development on response bias for specific emotions. Consistent with Study 1, response bias to facial sadness was significantly higher compared to bias to happiness and anger. Other studies, however, with similar stimuli have shown a higher bias to happiness compared to anger and sadness in school-aged children and adults (Durand et al., 2007).

For vocal emotional expressions, Study 3 showed that children's accuracy was at above-chance levels with chance defined as 25% (given the four response options) with some exceptions, such as low (50%) intensity angry and sad voices in preschoolers and low intensity (50%) happy voices in 8-year-olds (see Table 4.7). Results supported a developmental progression of the ability to recognise emotions from voices consistent with prior research (Hortacsu & Ekinci, 1992; Matsumoto & Kishimoto, 1983; Morton & Trehub, 2007). A developmental period of significant growth for the perception of emotional prosody was the transition from the school-aged years to adulthood; as adults were significantly more accurate than children but 6, 8 and 10-year-olds, did not differ from each other. Findings suggest that emotions are more difficult to recognise from prosody (i.e. compared to speech) by children and that this ability reaches maturity in the adult years. Previous studies showed no improvement in vocal emotion recognition from late childhood (10 years) to adolescence (Tonks et al., 2007; review by Tonks et al., 2009) and adult-like levels of accuracy to emerge at about 10-years of age (Baum & Nowicki, 1998; Shackman et al., 2007). What might explain the disprepancy between previous studies and the current study may be that previous studies used speech stimuli.

Regarding emotion-specific effects, Study 3 showed higher accuracy rates for angry, followed by happy and sad vocal expressions. Higher recognition for angry voices is consistent with findings from Study 1 and Study 2 and previous research in adults (Banse & Scherer, 1996; Maurage et al., 2007). Further, Study 3 made an original contribution in revealing effects of intensity on the recognition of emotional prosody. In particular, participants were more accurate in recognising higher compared to lower intensity vocal expressions. Finally, Study 3 extended previous research in adults (Banse & Scherer, 1996; Johnstone & Scherer, 2000; Wagner, 1993) by examining vocal emotion processing biases as well as recognition accuracy in children. Study 3 showed that 6-year-olds presented higher bias in the recognition of vocal emotional expressions compared to older (8 and 10-year-old) children and adults. In general, participants showed a greater tendency to attribute sadness, followed by anger and happiness to vocal expressions when uncertain about the emotion category. This higher bias towards vocal sadness is consistent with adult studies (review by Juslin & Laukka, 2003) and findings from Study 1.

Study 3 supported a positive relationship between recognition accuracy for facial and vocal expressions, suggesting that competence for facial and vocal emotion processing develop hand in hand, thus contributing to successful bimodal emotion processing (Banziger, Grandjean, & Scherer, 2009; Zupan, Neumann, Babbage, & Willer, 2009). In addition, children who were more accurate in identifying emotional expressions were also less likely to confuse emotions. Response bias in the recognition of facial expressions was positively associated with response bias to vocal expressions, suggesting underlying common inference processes in facial and vocal emotion processing.

Study 3 had some limitations. First, the study adopted a cross-sectional design. Future studies should aim to employ a longitudinal design to examine more systematically the development of facial and vocal emotion processing during childhood. Second, Study 3 did not include an adolescent group although sensitivity to emotional expressions may continue to develop from adolescence to adulthood (Thomas, De Bellis, et al., 2007).

A second aim of Study 3 was to examine the relationship between psychopathology and emotion processing in 4- to -10-year-old children and adults. Study 3 did not find significant associations between emotion processing and child psychopathology. The associations found, overall, were not strong. The only association which was close to significance after controlling for multiple comparisons was that between children's internalising problems and poorer accuracy in the recognition of sad facial expressions at high intensity. This finding is partly consistent with previous research demonstrating the salient role of sadness in emotion processing mechanisms implicated in internalising symptoms in children (Ellis et al., 1997; review by Hadwin & Field, 2010). Selective attention toward sad expressions and away from happy expressions has been demonstrated in adult populations with depression (review by Bourke, Douglas, & Porter, 2010; Surguladze et al., 2005). In adults, the only association that was close to significance was that between hyperactivity and bias to angry facial expressions. This is consistent with the hypothesis that hyperactive adults may present anger processing difficulties and a dysfunctional coping style for dealing with anger (Ramirez et al., 1997; Wender, 1995).

The overall lack of significant associations between emotion processing and child psychopathology in Study 3 contrasts with Study 1. A possible explanation for this inconsistency can be the differences in the vocal stimuli adopted. For example, Study 1 used linguistic stimuli while Study 3 used non-linguistic stimuli. It is possible that children in Study 1 presented difficulties in processing stimuli combining linguistic and emotional information (Study 1), but not emotional prosody stimuli (Study 3). Alternatively, differences may be due to the different sampling strategy used in two studies; Study 1 followed an enriched sampling strategy while Study 3 recruited a community sample of children. Therefore, the level of child symptoms was considerably lower in the present study compared to Study 1. Finally, Study 1 examined emotion processing in preschoolers while Study 3 recruited older (4- to 10-year-old) children. It is possible that emotion processing difficulties found in Study 1 change with development and that potential difficulties are more pronounced in younger children (Trentacosta & Fine, 2010).

4.4. General Discussion

Study 2 aimed to identify a suitable battery of vocal stimuli without language content. The selected battery presented a number of advantages over other batteries. In Study 2 children and adults identified emotions by prosodic cues at an overall accuracy of 50% (two times higher than chance level performance at 25% given the four response options), consistent with previous rates reported in the adult (Banse & Scherer, 1996; Scherer, Banse, et al., 2001) and child (Baum & Nowicki, 1998; Mitchell & Nowicki, 1998) literature. In Study 2 children were less accurate in recognising vocal emotion compared to adults. While Study 2 provided a pilot validation study of the vocal stimuli, Study 3 systematically examined effects of age, intensity and emotion type on recognition accuracy and response bias.

Study 3 indicated a developmental progression in the recognition accuracy for facial emotional expressions. In particular, preschoolers showed lower accuracy at recognising facial emotional expressions compared to all other age groups. Consistent with Study 1, recognition accuracy was higher for angry compared to happy and sad facial expressions. In addition, participants were more accurate in recognising high compared to low intensity facial expressions. There were no developmental effects on the recognition of specific emotions but the study showed a developmental pattern for the recognition of intensity in facial expressions, consistent with prior developmental research (Herba et al., 2006). Finally, preschoolers presented a higher bias to facial emotional expressions when compared to older (8 and 10-year-old) children and adults but there were no effects of development on response bias for specific emotions.

Study 3 showed that 4- to 10-year-old children could accurately recognise emotional prosody at above-chance levels. Results supported effects of development on the ability to recognise emotions from prosody, consistent with prior research using linguistic stimuli (Hortacsu & Ekinci, 1992; Matsumoto & Kishimoto, 1983; Morton & Trehub, 2007). A developmental period of significant improvement for the perception of emotional prosody was the transition from middle childhood to adulthood. Consistent with Study 1 and Study 2, the present study (Study 3) showed higher recognition accuracy for angry compared to happy and sad vocal expressions. Similarly, consistent with previous studies of the thesis, Study 3 showed higher response bias to sad compared to angry and happy vocal expressions and a decline in response bias to vocal expressions with development.

Finally, Study 3, consistent with Study 1, found that recognition accuracy of facial and vocal emotional expressions were positively associated, suggesting that abilities to recognise emotion from faces and voices develop in parallel during childhood.

In summary, Studies 1 and 3 showed that preschool and school-aged children were accurate at recognising facial and vocal emotional expressions with two independent sets of stimuli. Children's response bias to facial and vocal expressions and tendency to confuse emotions was low in both studies. Study 3 showed that the ability to recognise facial and vocal emotional expressions improved with age. In contrast, response bias decreased with development. There was generally limited evidence for emotion processing deficits and biases in children with psychopathology. Study 1 found vocal emotion processing deficits in children with externalising symptoms, which were not replicated in Study 3. In contrast, Study 3 showed few deficits in facial but not vocal emotion processing in children, which were not found in Study 1. These differences and the general lack of significant associations between emotion processing and child psychopathology in Study 3 may be accounted for by the different vocal stimuli, sampling strategy and age of children. In summary, the pattern of emotion processing difficulties in children with psychopathology remains unclear.

To further clarify the mechanisms of emotion processing in children with behaviour problems, more adequate methodologies are required which can bring researchers beyond the observable effects of performance-based studies and tap into cognitive processes underlying emotion processing. Electrophysiological methods are an excellent candidate in this direction, because they allow researchers to disentangle early perceptual from later cognitive processes in visual and auditory information processing (Johnson, 2005; Luck, 2005). Event-Related Potentials (ERPs) can provide reliable measures of different stages of visual and auditory emotion processing in a millisecond time resolution independent of behavioural responses (Batty & Taylor, 2003; Ponton, Eggermont, Khosla, Kwong, & Don, 2002) and can, therefore, reveal deficits that may not be evident in observable behaviour (Batty & Taylor, 2006; review by Itier & Batty, 2009). In parallel, ERPs can clarify whether possible deficits are emotion-specific. Chapter 5 further demonstrates the utility of supplementing performance-based studies with ERP studies providing a real-time index of neural processing of emotionally significant input.

5.1 Introduction to Event-Related Potentials

5.1.1 What is an ERP component?

The Event-Related Potential (ERP) reflects changes in the brain's electrical activity in response to a discrete stimulus or event. Event related potentials derive from the on-going EEG, a measure of continuous brain electrical activity over time, by averaging segments of EEG time-locked to a stimulus. As a result of averaging, the background noise, defined as the brain activity that is not related to the stimulus of interest, theoretically goes to zero. The ERP waveform plots as a function of time the change in voltage recorded on the scalp in response to an experimental condition. The ERP consists of a sequence of positive or negative deflections with peaks and troughs known as 'components' (i.e. time segments) which span a continuum between early and late brain activity and reflect stages of sensory and cognitive processing (Handy, 2005). Early or 'exogenous' components are determined by the physical characteristics of a stimulus whereas later or 'endogenous' components reflect cognitive characteristics of the stimuli and information processing in the brain (Picton et al., 2000). These components are characterised by their polarity, amplitude, latency, and functional significance. For example, a negative peak occurring at 100 ms post-stimulus onset is named 'N100' based on its latency (100 ms) and polarity (i.e. negative) and is related functionally to auditory processing (see Figure 5.1).

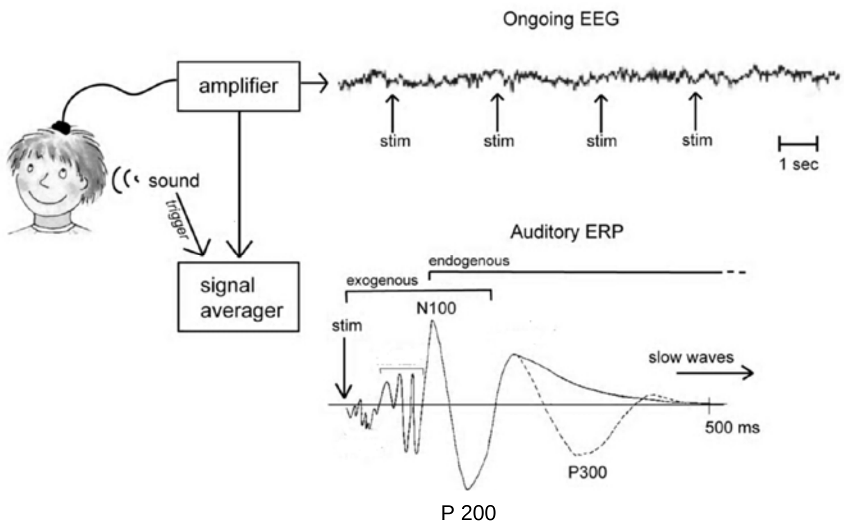


Figure 5. 1. Illustrative example of an auditory ERP generated by averaging several presentations of the same stimulus (Spreckelmeyer, 2006, p 36), used with permission.

5.1.2 The physiological basis of ERPs

The ERP represents the synchronous activity of populations of neurons within the brain. Electrodes placed on the scalp can record only a subset of brain's cortical activity (Fabiani, Gratton & Federmeier, 2007). The ERP signal is sensitive to particular neurons, known as radially oriented pyramidal cells (Allison, 1984). For brain activity to be detectable at the scalp, a large number of neurons must activate (or deactivate) synchronously. In addition, the electric fields associated with the activity of each individual neuron must be oriented in such a way as to cumulate at the scalp (Lorente De No, 1947). Therefore, only neurons with a specific spatial organization may generate scalp ERPs. Pyramidal cells are aligned in parallel and, as a result, when they are activated simultaneously they create summation of current in the same direction. This gives rise to an 'open field' which allows current to be conducted up to the scalp (Allison, 1984; Wood, 1987). Also, because pyramidal cells are perpendicular to the scalp, a greater signal can be propagated to the scalp surface. As opposed to pyramidal cells, randomly oriented cells may not produce a uniform or pronounced signal to be measured on the scalp (Kutas & Dale, 1997). Thus, ERPs cannot provide information about neural activity associated with 'closed' fields.

In summary, not only ERPs derive from particular types of neurons but also the geometric configuration of these neurons must be such that their activity summates, leading to an 'open field'. This implies that the neural activity differentiating the experimental conditions may not have the right properties to be detectable on the scalp.

It is believed that it is the summation of post-synaptic (dendritic) potentials of simultaneously activated cortical neurons that give rise to event-related potentials (Allison, Woods & McCarthy, 1986). The postsynaptic potentials which provide the current that is detected by ERPs can be excitatory or inhibitory (Allison et al., 1986). Excited or inhibited neurons consist of positive or negative current in the cell respectively. Excitatory or inhibitory input from a neighbouring cell can lead to alterations in the charge of a post-synaptic cell, thus creating a dipole which can be measured with scalp electrodes. Specifically, when an inflow of positive ions in the cell is caused by excitatory input from a neighbouring axon, negatively charged ions are left in the extracellular space. These ions travel down through the cell and exit back into the extracellular space thus creating a separation of charge (dipole). When an inflow of negative ions in the cell is caused by inhibitory input from a neighbouring axon, positive charge is left in the extracellular space. As negative ions travel down the cell and exit in the extracellular space this also creates a dipole. A negative deflection can be recorded if negative ions are closer to the scalp whereas a positive deflection is recorded if positive ions are closer to the scalp (Nelson &

Monk, 2001). This implies that a positive deflection, as measured by electrodes placed on the scalp, can be the result of either an inhibited cell's dendrites (positive extracellular ions) located closer to the scalp or an excited cell's dendrites (negative extracellular ions) which are located farther from the scalp. Scalp recorded ERPs, therefore, cannot provide information about the nature of the activation (positive or negative) (Wood, 1987).

5.1.3 Strengths and weaknesses of ERP technology

The main advantage of ERPs is that they can provide useful information about the timing of neural events. ERPs provide exquisite temporal resolution and high sensitivity to and specificity for aspects of cognitive processing. In addition, the ERP technique is popular for use with young children because brain activity is relatively easy to record, the signal is relatively robust and less sensitive to movement artifacts compared to fMRI (De Haan & Thomas, 2002). The ERP technique is a non-invasive method best suited for studying young children compared to other techniques (i.e. functional magnetic resonance imaging - fMRI, positron emission tomography -PET) which are constrained by ethical and practical limitations.

Despite the valuable information that ERPs can provide, it is equally important to recognize the limitations of ERP data. As seen above, ERPs are only sensitive to a limited subset of cortical neurons. It should be acknowledged that the sensitivity of the ERPs to the different neural ensembles engaged in processing different types of stimuli rather than the special salience of the stimuli might account for a particular ERP effect. In addition, the relationship between an electrical field observed on the scalp and the brain regions giving rise to that field is not transparent (Otten & Rugg, 2005). Under certain circumstances (high-density electrodes etc.), methods such as Independent Component Analyses (ICA) and Brain Electrical Source Analysis (BESA) can be employed to infer information about underlying sources. Such approaches can represent variations in surface activity in terms of variations of the activity of a few underlying brain structures (Fabiani, et al., 2007). However, these measures are limited by anatomical and functional information which can be obtained with other methods including MRI, fMRI and PET. Such methods have high spatial resolution (on the order of millimetres) but poor temporal resolution. It is commonly recommended that rather than replacing ERPs, a combination of ERP and imaging methods can provide a more complete (i.e. spatio-temporal) analysis of information processing (de Haan & Thomas, 2002; Fabiani, et al., 2007).

ERP data are often constrained by a number of additional limitations. Inferences based on the amplitude and latency of ERP effects should be considered critically. For an ERP signal to be reliable a large number of trials of the same experimental condition need to be averaged (see Figure 5.1). In addition, an ERP waveform is a valid measurement of the ERP to the extent that noise has been removed from the averaged waveform. Averaging must be sufficient to make the signal (i.e. the event-related response) distinguishable from noise (Picton, et al., 2000). Many of the inferences one can make from ERP data rely on assumptions that may not be satisfied. To the extent that the ERP signals are constant across trials, the noise is random across trials and the ERPs are independent of the background noise, the signal to noise ratio is increased by the square root of the number of trials included in the average (Luck, 2005).

However, by adopting a signal averaging procedure the above assumptions may be violated. For instance, if the latency of ERPs varies from trial to trial, then the amplitude of the ERP component in the average will be reduced and distorted in shape (latency jitter). Consequently, the average ERP waveform will not be representative of the component's amplitude and morphology of an individual trial. Thus, a difference in the amplitude of an ERP component between experimental conditions or subject groups could be the result of a difference in the amount of latency jitter rather than a real difference in ERP amplitude. This variability of ERPs in terms of amplitude and latency limits the extent to which inferences can be drawn from ERP data (but see Spencer, 2005 for a discussion on single-trial ERP analysis).

Importantly, comparisons between groups should consider differences in variability between the groups. When studying healthy individuals, the grand-average waveforms, representing ERP data at a group level, may miss important information which is available at single-subject level. In addition, in light of the large between-subject variability of ERPs, when studying clinical cases the use of grand-average waveforms can produce misleading results as clinical groups tend to be small and heterogeneous. For example, the finding of smaller amplitudes to a particular experimental condition in clinical patients compared to controls may be explained by the increased latency variability in the clinical group. Therefore, the variability of ERP measurements (latency and amplitude) in clinical groups should be assessed carefully.

In summary, ERPs present a number of advantages including high temporal resolution and ability to provide information about the timing of neural events. Also, ERPs can be used with a wider range of ages (i.e. infants) compared to other methods (i.e. MRI, PET). However, the relative insensitivity of ERPs to subcortical sources and the variability of the ERP signal limit the conclusions that can be drawn for ERP data.

5.1.4 Quantification of ERP components

There are alternative procedures for ERP component identification. Different techniques have different advantages and disadvantages and the preferred method of analysis will depend on the hypothesis of a given experiment (Handy, 2005). A review of the most common techniques and a discussion of their strengths and weakness are presented below.

One way to quantify ERPs is to take a *peak latency measure*. Peak latency can be calculated by measuring the interval (in ms) between a triggering event and the peak in the waveform. This can allow determining the time point at which the waveform reaches maximum or minimum within a specified time window. A problem with peak analysis is that the components in the single epochs underlying the average may be affected by substantial latency jitter. A method for reducing latency jitter is the Woody filter which assumes a constant form of the component across single epochs and cross-correlates a segment of each single epoch with a template (Woody, 1967). A second limitation with peak analysis is that the individual ERPs may overlap to different degrees and can often form one broad complex rather than be alligned in sequence.

A different method to quantify ERP components is to measure the amplitude of ERPs. One way to achieve this is to take a *peak amplitude measure*. This includes computing the amplitude at the time point where the component reaches it maximum amplitude. A peak amplitude measure can be taken when the component has a clearly defined peak. In cases when the component has a more heterogeneous morphology and no definite point at which to measure peak amplitude, then it is typical to take a *mean amplitude measure* (Fabiani et al., 2007). This includes the average amplitude over a time window that includes the component of interest (either baseline-to-peak or peak-to-peak). *Baseline-to-peak amplitude* can be obtained by measuring the voltage difference between the voltage at a peak point and a baseline level. This procedure scales the waveform such that the mean across the baseline window is equal to zero μV. However, a limitation of this method is that it may be sensitive to noise or nonlinear fluctuations in the baseline time window. The baseline period should be long enough to average out noise fluctuations in the average waveforms. Shorter baselines are more sensitive to residual voltage fluctuations compared to longer (i.e. 100 ms +) baseline time windows (Picton, et al., 2000).

An alternative approach to quantify the amplitude of an ERP component is to take a *peak-to-peak amplitude* measure. This is is computed by measuring the peak relative to an adjacent peak (or though) in the waveform. The advantage of this method is that it remains free from residual noise, DC shifts (very slow EEG activity) and other potential confounding artifacts in the prestimulus baseline (Picton et al., 2000). The peak-to-peak method can be a real index of temporally localised activity in cases in which the peaks of interest are superimposed on a slower wave or a sloping baseline shift. In addition, peak-to-peak amplitude measurement is suitable when a neighbouring peak-trough ensemble is thought to reflect the same functional process.

A final method of ERP quantification is to measure *onset latency*. This includes determining the latency at which the component began. A component's onset may be used to measure the beginning of a particular stage of information processing. For example, the measurement of onset is particularly useful when studying the lateralized readiness potential, because the onset is closely related to the decision processes that initiates selective response activation. A challenge with this approach, however, is to detect the timepoint at which the waveforms begin to deviate from some baseline state (Handy, 2005).

5.1.5 Review of ERP Components

Conceptually, ERPs are considered to be neural manifestations of psychological functions. A review of the functional significance (i.e. information processing) of some ERP components is presented below.

The P100 (P1) is an early latency positive potential occurring at 100 ms post stimulus and reflects early sensory processing of visual information and selective or correctly directed attention (Harter, Miller, Price, LaLonde, & Keyes, 1989; Hillyard & Anllo-Vento, 1998; Luck, Fan, & Hillyard, 1993). The P1 is differentially sensitive to faces compared with objects (Itier & Taylor, 2002, 2004; Taylor, Edmonds, McCarthy, & Allison, 2001). The source of the P1 is localised in the right occipitoparietal region (Utama, Takemoto, Koike, & Nakamura, 2009). The P1 to facial emotion is elicited as early as 94 ms in healthy adults (Batty & Taylor, 2003) and as early as 140 ms in infants (Nelson & de Haan, 1996). The P1 to emotional faces peaked at 125 ms in 5- to 9-year-old children (Dennis, Malone, & Chen, 2009). The P1 was sensitive to the emotional valence of facial expression in specific contexts (i.e. colour background) in adults (Frühholz, Fehr, & Herrmann, 2009).

The N100 (N1) is a negative component occurring at 100 ms post stimulus. The N1 consists of three subcomponents N1a, N1b and N1c (Bruneuau & Gomot, 1998 ; review by Näätänen & Picton, 1987; Velasco & Velasco, 1986) and reflects sound detection, early attentional orienting and stimulus evaluation (Bruneau, Roux, Guerin, Barthelemy, & Lelord, 1997; review by Näätänen & Picton, 1987). The frontocentral N1a is thought to reflect stimulus detection, the temporal N1b stimulus discrimination (Samson, Mottron, Jemel, Belin, & Ciocca, 2006) and the N1c subjects' arousal (Picton et al., 2000). The auditory N1 in children emerges at 3-4 years (Ceponiene, Rinne, & Näätänen, 2002) and is sensitive to age (Näätänen, 1992) with progressive changes in its morphology and distribution with age (Pang & Taylor, 2000). In 4- to 8-year-olds, the auditory N1 peaks around 140 ms at midline and 170 ms at temporal sites (Bruneau et al., 1997). In 9-year-olds the neural sources of the N1 map on superior temporal lobes (Ceponiene et al., 2002).

The N170 is an occipitotemporal negative potential occurring at 170 ms post stimulus onset linked to sensitivity in processing information from human faces (Bentin & Carmel, 2002; George, Evans, Fiori, Davidoff, & Renault, 1996; Taylor, McCarthy, Saliba, & Degiovanni, 1999). The N170 presents shorter latency and larger amplitude to faces compared to non-face stimuli (Bentin, Allison, Puce, Perez, & McCarthy, 1996). The N290 and the P400 may represent developmental precursors of the adult N170 (de Haan, Johnson, & Halit, 2003). The N170 evoked by facial emotion is maximal at 190 ms at parietal occipital sites in 5- to 9-year-old children (Dennis et al., 2009). The N170 consists of subcomponents N170a and N170b with medial inferior source and medial and lateral temporal sources respectively which merge with the adult-like N170 in late adolescence (review by Taylor, Batty & Itier, 2004).

The P200 (P2) is a positive component occurring at around 200 ms post stimulus which reaches its maximal at centroparietal regions. The P2 is larger for stimuli containing target features (Luck & Hillyard, 1994a). The P2 has been associated with stimulus identification during emotional speech perception (Schirmer, Zysset, Kotz, & Yves von Cramon, 2004) and can increase with stimulus intensity. The auditory P2 does not differ in overall amplitude between 9-year-old children and adults, however, in children the P2 is inverted in polarity frontally (Ceponiene et al., 2002). In posterior areas children's auditory P2 has been found to be larger in amplitude than in adults and widely distributed over the scalp in adults compared to 9 and 5-year-old children (Ceponiene et al., 2002).

The P300 (P3) is a positive component occurring at 300-600 ms post stimulus which is parietally maximal (Sutton, Braren, Zubin, & John, 1965). A frontally maximal P3a and parietally maximal P3b have been identified in adults (Squires, Squires & Hillyard, 1975). The P3a is thought to reflect attentional capture, allocation of cognitive resources, context updating and working memory (review by Banaschewski & Brandeis, 2007; Donchin, 1981). From middle childhood onward the P3a with a frontal maximum at midline from 250 to 500 ms has been associated with attentional engagement and sensory working memory when time locked to target stimuli in oddball paradigms (Nelson & McCleery, 2008). The P3b to target stimuli in oddball tasks has been observed from middle to late childhood with a parietal maximum at midline from 350 to 550 ms and has been associated with context updating relevant to memory storage (Nelson & McCleery, 2008).

The N400 (N4) is a centroparietal negative component occurring at 400 ms post stimulus which typically reflects semantic language processing and match/mismatch semantic integration in adults (Kutas & Hillyard, 1980, 1983). An N400-like response has been observed in toddlers reflecting semantic context match/mismatch (Nelson & McCleery, 2008). More recently, the N400 has been found to reflect integrative emotional prosodic and semantic processing in healthy adults (Schirmer, Kotz, & Friederici, 2002, 2005) and be functionally related to perception of emotional prosody in healthy adults (Schirmer & Kotz, 2006). The generators of the N400 include the anterior medial temporal lobes (McCarthy, Nobre, Bentin & Spencer, 1995).

The Slow Wave (SW) is a frontally-negative, parietally-positive slow potential of long duration, temporally overlapping with the P3a and P3b, with larger amplitudes to task-relevant stimuli (Ruchkin, Johnson, Mahaffey, & Sutton, 1988; Ruchkin & Sutton, 1983). The Slow Wave activity may contain an early negative component in children, which decreases with age and a late positive component, not affected with development (Johnstone & Barry, 1999). In infants the positive slow wave from 800 to 1700 ms is thought to reflect memory updating during face recognition. A return to baseline has been suggested to reflect that stimuli do not require memory updating (de Haan & Nelson, 1997; DeBoer, Scott, & Nelson, 2005).

5.2 The Neural Development of Emotion Processing

5.2.1 The Neural Development of Facial Emotion Processing

Despite the relatively rich behavioural evidence, little is known on the development of neural systems underlying emotion processing in children (Herba & Phillips, 2004). This constitutes a major limitation in the developmental literature.

Emotional processes are part of the evolution of the human brain and in order to understand the sources of human emotional feelings it is essential to explain how affect emerges from brain related processes (Panksepp & Panksepp, 2000). Current debates focus on whether brain structures are specialised for processing social information or whether social cognition is part of general cognitive processes applied to social behaviour (Adolphs, 2009). Research has lent empirical support to the proposal that there is a network of specific brain areas preferentially involved in the processing of social information, a network often referred to as the ‘social brain’ (Adolphs, 2010; Brothers, 1990; Leppanen & Nelson, 2009; Johnson et al., 2005). Unveiling the neural basis of individual differences in understanding others’ emotions can advance knowledge on ways such social processing components relate to prosocial behaviour (Singer & Lamm, 2009). Event-related potentials, in particular, are a suitable, noninvasive, methodology to understand the timing (in a millisecond resolution) of the sensory, perceptual and cognitive processes underlying social information processing (Nelson & Luciana, 2001). ERPs can inform our understanding of whether neurally separate components have the potential to be specialised for processing emotional information (de Haan & Gunnar, 2009).

In the adult literature, theoretical models for recognising facial emotional expressions emphasise that conceptual knowledge of the emotion signalled by the face is preceded by early perceptual processes by highly salient stimuli (Bruce & Young, 1986; Haxby, Hoffman, & Gobbini, 2000). According to Adolphs (2002), in healthy adults fast early perceptual processing (i.e. structural encoding) of highly salient stimuli takes place in the pulvinar thalamus, the amygdala and superior colliculi during the first 120 ms from stimulus onset. This is followed by an early activation of the superior temporal gyrus, fusiform face area and basal ganglia implicated in more detailed perception and recognition of the stimulus (Adolphs, 2002). Finally, there is late activation (i.e. at about 300 ms from stimulus onset) of the fusiform face area, superior temporal gyrus and orbitofrontal cortex responsible for the conceptual knowledge of the emotion signalled by the face. Thus, whereas subcortical routes such as the amygdala are specialised for very fast, automatic and coarse processing of the stimulus (i.e. global face characteristics), a 'slower cortical route' is implicated in processing of more detailed information (i.e. high spatial frequency) in faces (Pourtois, Grandjean, Sander, & Vuilleumier, 2004; Pourtois, Schwartz, Seghier, Lazeyras, & Vuilleumier, 2005; Vuilleumier, Armony, Driver, & Dolan, 2003).

In healthy adults, processing of facial emotion has been found to activate a number of cortical areas. For instance, the anterior cingulate and lateral prefrontal cortex have been found to be implicated in processing angry faces (Blair, Morris, Frith, Perrett, & Dolan, 1999; Harmer, Thilo, Rothwell, & Goodwin, 2001), the orbitofrontal and inferior prefrontal cortex in processing happy faces (Dolan et al., 1996; Phillips, Bullmore, et al., 1998) and the anterior, medial temporal regions in processing sad faces (Blair et al., 1999; George, Ketter, Parekh, Herscovitch, & Post, 1996). Facial emotional expressions (Sato, Kochiyama, Yoshikawa, & Matsumura, 2001) and affective judgements of faces (Pizzagalli et al., 2002) also modulated early activity in the occipitotemporal cortex. Finally, the basal ganglia and the insula have been found to be implicated in processing of facial expressions of disgust (Phillips, Young, et al., 1998).

Beyond cortical areas, models of facial emotion processing highlight the role of sub cortical routes, such as the amygdala (Adolphs, Tranel, & Damasio, 2003; Calder et al., 1996; LeDoux, 2003; Morris, DeGelder, Weiskrantz, & Dolan, 2001; Morris et al., 1996; Phelps & LeDoux, 2005). Research with healthy adults and patient populations has revealed activation of the amygdala in response to fearful (Calder, Lawrence, & Young, 2001; Morris, Öhman, & Dolan, 1999; Phillips, Young, et al., 1998), sad (Blair et al., 1999; Schneider, Habel, Kessler, Salloum, & Posse, 2000) and to a lesser extent, angry (Critchley et al., 2000; Hariri, Bookheimer, & Mazziotta, 2000) and happy (Breiter et al., 1996; Wright et al., 2001) facial expressions. The above activation patterns persisted even when the participants performed an irrelevant (e.g. gender decision) task (Sprengelmeyer, Rausch, Eysel, & Przuntek, 1998). Lateralisation effects on emotion processing, in favour of the right cerebral hemisphere, have also been reported in the adult literature; although evidence remains inconclusive (Adolphs, 2002). This is partly due to competing hypotheses that the two hemispheres are differentially important in processing emotion; such that the right hemisphere is responsible for processing negative whereas the left hemisphere specialised in processing positive emotions (Borod et al., 1998).

Evidence on the neural underpinnings of facial emotion processing in children and adolescents is more limited. Developmental social neuroscience frameworks can be valuable for the study of facial emotion processing for a number of reasons.

Development provides a unique opportunity to study the neural correlates of emotion processing as they emerge at different ages (de Haan et al., 2003; Grossmann & Johnson, 2007; Johnson et al., 2005). This approach can provide answers to the question of ‘when’ the developing brain begins to become ‘tuned’ to its social environment. Second, developmental perspectives can clarify the specialisation over time of specific (ERP) components which tap onto different cognitive processes (de Haan & Thomas, 2002; Nelson & McCleery, 2008), as neural substrates implicated in social processing change and become more specialised (Johnson, Grossmann, & Kadosh, 2009). For instance, brain regions which initially respond to a range of stimuli such as inanimate objects can later in development confine their neural activity to another class of objects namely human faces (Johnson et al., 2005). In addition, ERP methods are useful in conceptualising not only typical but also atypical development as ERPs can reveal individual differences which may not be evident in observable behaviour. For example, adolescents with ADHD have been found to present enhanced occipital N170 responses to facial expressions of anger, possibly suggesting over-processing of anger (Williams et al., 2008). Individual differences in children’s neural responses to emotional stimuli may serve as one of several markers that can aid early identification of children at risk for developing psychiatric conditions (Elsabbagh & Johnson, 2007).

The infant literature has provided useful insights into the development of the neural mechanisms responsible for recognising emotion from faces (Nelson & de Haan, 1996). Research has shown that 6- to 12-month-old infants displayed an N290 in response to human faces and a later, more lateral, positive component at about 400 ms from stimulus onset (de Haan et al., 2003). A recent functional magnetic resonance imaging (fMRI) study with infants, for example, has shown that occipitotemporal pathways underlying face processing may be mature by 2 to 3 months of age (Tzourio-Mazoyer et al., 2002). At 3 months of age the infant brain differentially responded to objects as a function of how other people reacted to them such as an adult expression of fear toward an unfamiliar object (Hoehl, Palumbo, Heinisch, & Striano, 2008). ERP research suggests that the ability to differentially process a range of facial emotional expressions (i.e. angry, happy, neutral and fearful) develops during infancy (de Haan, Belsky, Reid, Volein, & Johnson, 2004; Kobiella et al., 2008; Nelson & de Haan, 1996). A recent study showed that 7-month-old infants displayed a larger negativity to happy faces at around 400 ms from stimulus onset at frontal, central, temporal and parietal sites whereas angry faces elicited a larger negativity at around 410 ms at occipital sites in 12-month-olds, suggesting that a heightened neural sensitivity from happy to angry faces develops from 7 to 12 months (Grossmann, Striano, & Friederici, 2007).

Despite the relatively higher number of infant studies, less is known about the neural development of facial emotion processing in childhood and adolescence with the majority of studies emerging during recent years. Recent research has shown that 5- to 8-year-old children exhibited similar patterns of activation of face processing areas (i.e. fusiform face area) as adults, although this activation extended also to non-face objects (Scherf, Behrmann, Humphreys, & Luna, 2007). A similar study found that bilateral brain selective activation for faces compared to houses increased in older (10- to 12-year-old) compared to younger (8- to 10-year-old) children, suggesting that face processing continues to become more specialised with development (Aylward et al., 2005). There is recent evidence that in 5- to 8-year-old children, a late positive potential (LPP) at occipitoparietal areas increased from 500 to 1500 ms following viewing of affective (e.g. sad faces) compared to neutral pictures indicating that, as in adults, the LPP was sensitive to emotional meaning of visual stimuli in children (Hajcak & Dennis, 2009).

Similarly, studies have found that in 5- to 14-year-olds middle and superior temporal regions were activated by processing angry, happy, sad and fearful facial expressions (Batty & Taylor, 2006; de Haan, Nelson, Gunnar, & Tout, 1998), as in the case of adults (Batty & Taylor, 2003). Research with 10-year-old children has shown that implicit processing of fearful, disgust and sad faces activated similar brain regions to those associated with facial emotion processing in adults, including the amygdala and parahipocampal gyrus, insula and cingulate gyrus, as well as the fusiform and superior temporal gyri (Lobaugh, Gibson, & Taylor, 2006). Also, a recent study showed that 3- to 8-year-old children, but not adults, showed greater amygdala activation to happy compared with angry faces; possibly suggesting a positivity bias in young children (Todd, Evans, Morris, Lewis, & Taylor, 2011).

Research with adolescents has shown activation of the fusiform gyrus and prefrontal cortex during facial emotion processing (Wang, Mirella, Ahmad, Marian, & Susan, 2004). Research has shown a focal activation of medial prefrontal regions in early adolescence and an increase in activation of posterior (temporal) regions in adulthood during mentalising tasks (Blakemore, Ouden, Choudhury, & Frith, 2007). Similar work in 13- to 17-year-olds has shown bilateral amygdala activation in response to happy, but not sad, faces when compared to neutral faces (Yang, Menon, Reid, Gotlib, & Reiss, 2003). Finally, it should be noted that general structural development and synaptic reorganisation during adolescence may partly explain brain activity patterns in this developmental period (Blakemore, 2008).

In summary, existing evidence points to the occipitotemporal cortex and the amygdala as the key neural pathways involved in facial emotional expression processing in adults and children. The majority of ERP work on facial emotion processing has focused on adults and infants; ERP evidence with school-aged children is limited. Although a range of different brain areas have been suggested to underlie processing of facial emotional expressions, less is known about the neural timing of such processing. The following section will discuss the three most prominent ERP components implicated in facial emotion processing in children.

5.2.1.1 The P1

The P1 has been found to be sensitive to happy and fearful expressions as early as 190 ms in 7-month-old infants (Nelson & de Haan, 1996). Despite extensive research in adults (Eimer & Holmes, 2002; Pourtois et al., 2004) and infants (Moulson, Westerlund, Fox, Zeanah, & Nelson, 2009; Nelson & de Haan, 1996) showing larger and faster P1 to fearful compared to neutral faces, few studies have investigated the P1 in response to facial emotional expressions in typically developing preschool to school-aged children (Batty & Taylor, 2006; Dennis et al., 2009; Todd, Lewis, Meusel, & Zelazo, 2008). The P1 has been observed to be maximal at right parietal occipital sites at latencies of 120 ms for school-aged children (Batty & Taylor, 2006) and 200 ms for 3- to 4-year-olds (Dawson, Webb, Carver, Panagiotides, & McPartland, 2004). Earlier P1 latencies for fearful compared to surprised and neutral faces have also been found in a recent study (Batty & Taylor, 2006) these effects, however, were found only with younger (4- to 7-year-old) compared to older (8- to 14-year-old) children.

Similarly, a recent study found that P1 amplitudes were larger in 3- to 4-year-olds compared to older (5- to 6 year-old and 7- to 8-year-old) children when viewing fearful than neutral faces (Vlamings, Jonkman, & Kemner, 2010). A study using an attention task following emotional distractors did not find significant differences in P1 latency between neutral and negative (i.e. sad, fearful) emotions in 5- to 9-year-olds, although P1 latencies were faster to fearful than sad faces (Dennis et al., 2009). Similarly, no emotion effects on the P1 were found in 4- to 6-year-old children in a Go-Nogo task with happy and angry familiar and unfamiliar faces (Todd et al., 2008).

The P1 has been suggested to reflect top-down attentional influences on early face processing rather than being a 'face-specific' component (de Haan et al., 2003). This model also seems to fit findings from studies showing that emotion effects on the P1 in 3- to 8-year-olds were present only when detailed information in faces (i.e. eye contours) was provided (Vlamings et al., 2010). This interpretation is compatible with adult models of facial emotion processing suggesting that rapid extraction of information related to emotion precedes more fine-grained perceptual processing (Vuilleumier & Pourtois, 2007).

5.2.1.2 The N170

The N170 is an occipitotemporal negative potential, following the P1, that is traditionally linked to sensitivity in processing information from human faces (Bentin et al., 1996; Taylor et al., 1999). The infant N290 with longer latencies and smaller amplitudes than the adult N170 has been suggested as a developmental precursor to the adult N170 implying a process of gradual specialisation of cortical face processing with development (de Haan, Pascalis, & Johnson, 2002; Halit, Csibra, Volein, & Johnson, 2004; Halit, de Haan, & Johnson, 2003). By the age of four, the N170 reached an adult-like morphology and could respond differentially to faces compared to objects (Taylor et al., 2001; Taylor et al., 1999). In addition, the N170 elicited by faces and eyes, underwent developmental change from 4-15 years including a decrease in peak latency and an increase in amplitude (Taylor et al., 1999), but a completely adult-like modulation of N170 amplitude was not evident until 13–14 years (review by Taylor et al., 2004).

Although the N170 has received particular attention from a developmental perspective of face processing (review by Grossmann & Johnson, 2007), it has less often been investigated in relation to emotion perception in particular. In adults, the N170 evoked by negative emotions peaked later compared to neutral and positive emotions and N170 amplitudes to fearful faces were larger compared to neutral and happy faces (Batty & Taylor, 2003). Although some studies have shown that the N170 was sensitive to facial emotion in adults (Batty & Taylor, 2003; Blau, Maurer, Tottenham, & McCandliss, 2007; Vuilleumier & Pourtois, 2007), other studies have not found facial emotion modulation of the N170 (Eimer & Holmes, 2002; Eimer, Holmes, & McGlone, 2003; Herrmann et al., 2002). In children, emotion effects on the N170 have been observed in older (14- to 15-year-old) compared to younger (4- to 12-year-old) children, with N170 amplitudes being larger for negative (i.e. anger, sad) compared to positive (i.e. happy) and neutral faces (Batty & Taylor, 2006). Similarly, the N170 was not sensitive to facial emotion in 4- to 6-year-old (Todd et al., 2008) and 5- to 9-year-old children (Dennis et al., 2009) or was sensitive to facial emotion only under conditions of faces presented with detailed information (i.e. those with high spatial frequency) (Vlamings et al., 2010).

Summarising the early latency components (P1, N170) to facial emotion, one could conclude that P1 is an index of global and 'superficial' processing of facial emotion that is present in younger children. The N170 on the other hand, indices more detailed sensitivity to facial emotion emerging during adolescence and in younger children it may reflect a reliance on a global, bottom-up type of face processing rather than finer grained processing.

5.2.1.3 The P3 and the Slow Wave

The late positive complex (P3/SW), from around 400 to 900 ms after stimulus onset, evoked by emotional compared to neutral pictures in occipital, temporal and parietal areas is thought to reflect increased perceptual and attentional processes involved in motivationally salient stimuli (Sabatinelli, Lang, Keil, & Bradley, 2007; Schupp et al., 2000), a pattern of effects known as 'motivated attention' (Lang, Bradley & Cuthbert, 1997). In adults, emotional pictures (e.g. of happy families) elicit a larger late positive potential (400–700 ms) and a larger positive slow wave (1000–6000 ms) over centroparietal areas (Pastor et al., 2008). A late positive component has been implicated in face processing (de Haan et al., 2003; de Haan & Thomas, 2002) and facial emotion processing (Nelson & de Haan, 1996) in infants. The positive slow wave activity (PSW) occurring 800-1700 ms after stimulus onset in infants, is hypothesised to reflect memory updating whilst the negative slow wave activity (NSW) with the same latency range, is suggested to reflect detection of novelty (de Haan & Nelson, 1997; Nelson & de Haan, 1996; Nelson & de Haan, 1997). A return to baseline (i.e. zero) from the PSW and NSW has been observed for stimuli not requiring memory updating and not detected as novel in a familiar face recognition memory task in infants (de Haan & Nelson, 1997).

The late positive component has been shown to be larger following negative (i.e. angry) than positive (i.e. happy) faces in children (Kestenbaum & Nelson, 1992; Lewis, Todd, & Honsberger, 2007), as in adults (Cunningham, Espinet, DeYoung, & Zelazo, 2005) and also following negative emotion induction (Lewis, Lamm, Segalowitz, Stieben, & Zelazo, 2006). The later frontal slow wave (390-450 ms), although positive in adults (Batty & Taylor, 2003) has been found to be negative in children (Batty & Taylor, 2006). Despite a decreased negativity with increasing age between 300 and 390 ms, there were some marginal effects of emotion on the frontal slow wave in 4- to 15-year-olds with happy faces eliciting a smallest negativity compared to disgust, fear and sadness (Batty & Taylor, 2006). Similarly, no effect of facial emotional expression has been found on the N400 in 8-year-olds (Battaglia et al., 2005). In contrast, effects of emotional expression (happy more positive than neutral faces) have been seen in adults on frontocentral mean amplitudes from 270-420 ms (Batty & Taylor, 2003). Another study found a larger posterior negative component around 300 ms to fearful compared to neutral faces in 3- to 4-year-olds (Dawson et al., 2004).

5.2.2 The Neural Development of Vocal Emotion Processing

Human voices are special auditory stimuli and are processed differentially by the human brain, in comparison to non-human sounds, in a specialised brain region consisting of the upper temporal sulcus (Belin & Zatorre, 2000; Belin, Zatorre, Lafaille, Ahad, & Pike, 2000). A 'voice specific response' (VSR) has been identified peaking around 320 ms after stimulus onset in response to human voices compared to other sounds (i.e. animal, mechanical and musical sounds), possibly reflecting allocation of attention to salience of vocal stimuli (Levy, Granot, & Bentin, 2001, 2003). Recently, in a voice/non-voice auditory discrimination task, a 'voice sensitive response' emerged as early as 164 ms post stimulus onset and peaked around 200 ms on frontocentral (positivity) and occipital (negativity) sites (Charest et al., 2009). This suggests that the neural processing of faces ('face-specific' N170) and voices occur at similar time points explaining the integration of such signals in real-life social interactions (Campanella & Belin, 2007). This highlights the importance of studying voice perception for an ecologically valid assessment of non-verbal social communication.

The role of the amygdala has been highlighted by the vast majority of fMRI studies, as a key structure in vocal emotion processing in healthy adults. For example, a recent fMRI study with healthy adults using a gender identification task with positive (i.e. laughs), negative (i.e. cries), and neutral (i.e. coughs) vocalisations found bilateral amygdala activation to all emotional vocalisations compared to neutral vocal stimuli and stronger right amygdala activation in response to happy vocalisations (Fecteau, Belin, Joanette, & Armony, 2007). Other fMRI research has identified a widespread network, including the right middle temporal gyrus and inferior frontal gyrus, showing greater activation to happy compared to angry voices (George, Parekh, et al., 1996). A similar study showed that processing affective prosody in an emotion identification task activated the posterior superior temporal sulcus and dorsolateral frontal areas (Wildgruber et al., 2005). Impaired recognition of vocal fear and anger, despite normal speech perception and hearing, has been found in a case study with a patient with amygdala lesions (Scott et al., 1997).

Models of vocal emotion processing have suggested pre-attentive evaluation of vocal emotion stimuli occurring in the amygdala and also attention modulated pathways: a selective attention bottom-up mechanism involving the amygdala and a top-down route involving the frontal lobes (Scherer, 2005; review by Compton, 2003). Connectivity studies have shown that evaluation of affective prosody requires prior analysis of acoustic aspects in the temporal cortex, before transfer of information occurs from the temporal cortex to the frontal lobes (Ethofer et al., 2006). An fMRI study using an implicit dichotic listening task showed that processing anger prosody in adults was independent of attentional response at superior temporal sulcus and the amygdala but attention dependent at orbitofrontal cortex and the cuneus (Sander et al., 2005) . This study also showed right hemisphere activation to vocal anger in the ‘attention’ condition. A similar fMRI study found involuntary response to vocal anger independent of voluntary attention in middle superior temporal sulcus thus replicating the above finding (Grandjean et al., 2005). These findings partly support automatic appraisal theories (Scherer et al. 2001) suggesting that vocal emotion processing can occur fast and pre-attentively at least in some brain areas.

In regards to the lateralisation of emotional prosody perception, there is some evidence that right regions, involving the medial temporal gyrus and medial frontal gyrus, were activated by processing prosody, whereas left regions were activated by processing semantics, under both directed attention and passive listening (Mitchell, Elliott, Barry, Cruttenden, & Woodruff, 2003). However, other studies, found that emotional prosody was processed equally in both hemispheres (Kotz et al., 2003; Morris, Scott, et al., 1999).

Despite evidence on the brain structures, implicated in vocal emotion processing, less is known on the neural timing of such processing. A three-process model for the processing of emotional prosody has recently been suggested (Schirmer & Kotz, 2006).

According to this model (see Figure 5.2) a first sensory stage of processing involves the auditory processing areas. Differences in frequency or sound intensity peak at about 100 ms from stimulus onset as captured by the N1 (Ceponiene et al., 2002). At second stage, processing along the auditory 'what' pathway integrates acoustic information to deliver an emotional 'gestalt'. At around 200 ms emotional significance can be derived after integrating primary acoustic information (Schirmer et al., 2004). This pathway projects from the superior temporal sulcus (STS) and may be lateralized to the right hemisphere. At a third stage, emotional information is made available for higher-order cognitive processes. Evaluative judgments involving labelling emotional expressions involve activation of right inferior frontal gyrus and orbitofrontal cortex with effortful semantic processing activating the left inferior frontal gyrus (Schirmer & Kotz, 2006).

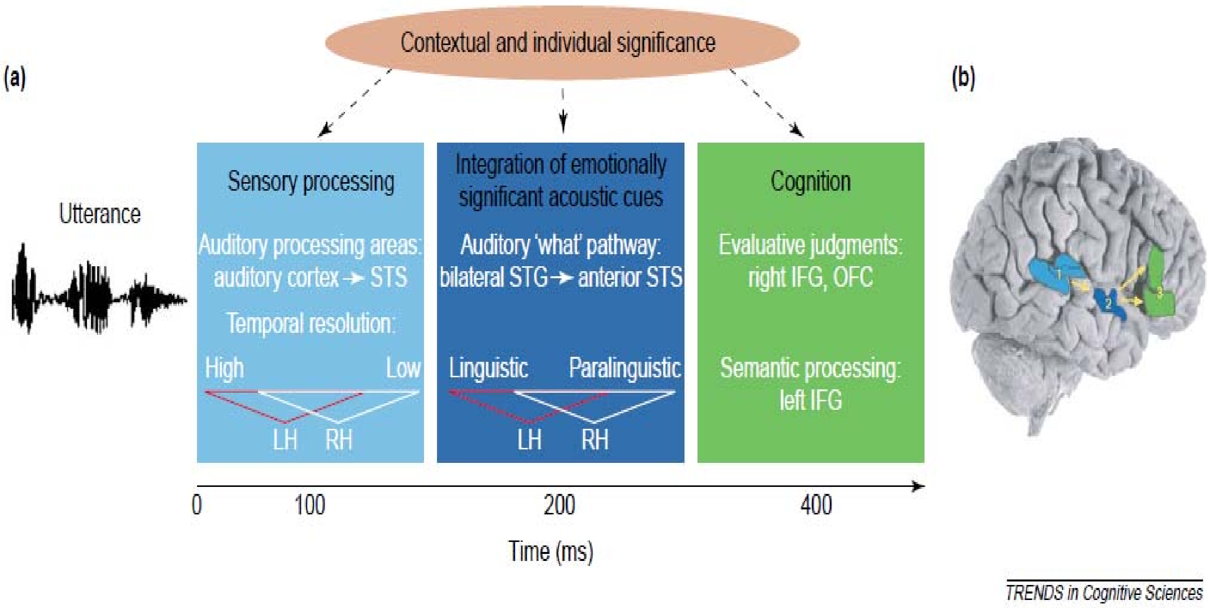


Figure 5. 2. A three-process model for emotional prosody processing (Schirmer & Kotz, 2006, p. 25). Figure reproduced with kind permission from Annett Schirmer.

Despite the above adult studies, less is known about the neural development of voice processing and vocal emotion processing in developmental populations.

Cerebral voice processing appears earlier than speech in human development (Belin & Grosbras, 2010). The newborn's brain, shortly after birth, shows greater activation in response to their mothers' voice compared to a strangers' voice (Beauchemin et al., in press), suggesting that recognition of vocal signals comprises an early developmental milestone. Earlier work has shown enhanced frontocentral P350 and N450 evoked by mothers' compared to strangers' voices in 4-month-old infants, suggesting that infants allocate more attention to process their own mothers' voices compared to unfamiliar voices (Purhonen, Kilpelainen-Lees, Valkonen-Korhonen, Karhu, & Lehtonen, 2004). The above findings highlight the importance of vocal signals in mother-child relationships.

One line of developmental research has investigated whether human voices are processed differentially by the developing brain in comparison to other sounds. Research has shown that the right posterior temporal cortex is sensitive to human voices compared to non-vocal sounds in 7-month-old infants (Grossmann, Oberecker, Koch, & Friederici, 2010). This same region was also sensitive to human voices in adults (Belin & Zatorre, 2000), suggesting some developmental continuity between 7 months and adulthood. However, 4-month-old infants did not show a 'voice-sensitive response' indicating that voice sensitivity in the posterior temporal cortex emerges between 4 and 7 months (Grossmann et al., 2010). Further, support for this derives from one fMRI study with 2- to 3-month-olds who failed to show a voice sensitive response in the temporal cortex when human speech was compared to non-speech sounds (i.e. music) (Dehaene-Lambertz et al., 2010).

A voice-sensitive response peaking around 200 ms after sound onset was observed at right temporal sites in 4- to 5-year-old children in a recent study comparing vocal to non-vocal sound processing (Rogier, Roux, Belin, Bonnet-Brilhault, & Bruneau, 2010). Vocal sounds elicited a positivity which began within 60 ms of stimulus onset and was most prominent in right temporal regions while non-vocal sounds evoked a negative N1c peak (~190 ms). The dissociation between vocal and non-vocal sounds was significant as early as 56 ms in frontal sites and 66 ms in right temporal sites (Rogier et al., 2010). A similar 'FrontoTemporal Positivity to Voice' (FTPV) component, with right hemisphere dominance, has been observed in healthy adult individuals (Belin & Zatorre, 2003; Belin et al., 2000). The above findings suggest some developmental continuity in voice processing between 5 years and adulthood.

A further question is when the developing brain begins to become 'tuned' to emotional information from voices. Useful insights into the developmental aspects of vocal emotion processing derive from infant studies.

In 7-month-old infants, a positive slow wave (500-1000 ms) over temporal areas was elicited by words with angry and happy prosody compared to a return to baseline in response to words with neutral prosody (Grossmann, Striano, & Friederici, 2005). This is consistent with fMRI studies in adults showing enhanced sensory processing of emotionally loaded (happy and angry) compared to neutral speech (Fecteau et al., 2007; Mitchell et al., 2003). In the same study, words with an angry prosody elicited a more negative ERP response (latency 450 ms) over frontocentral sites compared to words with happy or neutral prosody (Grossmann et al., 2005). Recently, near-infrared spectroscopy (NIRS) studies confirmed increased brain activation patterns in the posterior temporal cortex when hearing angry compared to neutral and happy prosody in 7-month-old infants (Grossmann et al., 2010). This pattern of findings has been suggested to indicate an increased sensory processing of threatening (i.e. angry) information in infants, as in adults (Ethofer et al., 2006; Grandjean et al., 2005). Further, 7-month-old infants recognised congruity between the emotional message conveyed by face and voice, as reflected by a larger parietal positive component (~600 ms) in response to face-voice pairs conveying congruent (i.e. happy) compared to incongruent (i.e. happy, angry) emotional information (Grossmann, Striano, & Friederici, 2006).

Evidence for some developmental continuity in the specialisation of the right hemisphere for processing positive emotions, has recently become available. For example, hearing happy voices, but not angry or neutral voices, tended to evoke an increased response in right inferior frontal cortex in 7-month-old infants (Grossmann et al., 2010), as in adults (Johnstone, van Reekum, Oakes, & Davidson, 2006). In addition, right hemisphere activation was larger to vocal compared to non-vocal sounds in 7-month-infants and modulation of this response by emotion was restricted to the right compared to the left hemisphere (Grossmann et al., 2010). This is consistent with adult findings on voice processing (Belin & Zatorre, 2000) and vocal emotion processing (Ethofer et al., 2006; Grandjean et al., 2005).

Beyond the above infant studies, however, research with preschool and school-aged children remains limited. In a recent study, unattended vocal anger but not happiness or sadness, in semantically neutral words, elicited a negative frontal component (~400 ms) in abused when compared to typical 7- to 12-year-old children (Shackman et al., 2007). However, no effects of emotion (angry, happy, and sad) or voice familiarity (mother, stranger) were reported on the amplitude of the P3b (570–770 ms) in typically developing children in this study. Using speech stimuli, a recent study reported no effect of vocal emotion (angry, happy) on the amplitude and latency of an early component (N1:100-200 ms) or the latency of a late (250-800 ms) negative component, in a group of 13 typically developing 9- to 11-year-old boys (Korpilahti et al., 2007). It is worth noting that both the above studies employed a small sample size of typically developing children and so may have had insufficient power to detect emotion effects.

In summary, the human brain begins to become sensitive to emotional information from voices at an early stage in development. However, no ERP studies have been conducted in typical school-aged children using non-speech emotional stimuli; therefore, the time course of emotional prosody perception in this age group remains unclear. The section that follows reviews the ERPs most frequently studied in vocal emotion processing.

5.2.2.1 The N1

The N1 is sensitive to differences in sound intensity or frequency of acoustic stimuli (Ceponiene et al., 2002; Näätänen & Picton, 1987) and reflects auditory behavioural orienting in 4- to 8-year-old children (Bruneau et al., 1997). There is evidence that the N1 to tone bursts starts to reach adult-like amplitudes from 7 years of age (Pang & Taylor, 2000). In adults, the N1 was evoked by angry and happy voices (Kotz & Paulmann, 2007). The N1 was elicited at frontal, central and parietal sites in healthy adults in response to sad exclamation deviants in an oddball task with emotional exclamations (i.e. Ooh!) expressing joy and woe (Bostanov & Kotchoubey, 2004; Kotchoubey, Kaiser, Bostanov, Lutzenberger, & Birbaumer, 2009). The N1 has been shown to have longer latencies (150 ms) and smaller amplitudes in 9- to 12-year-old children with Aspergers syndrome compared to control children during processing of affective prosody (Korpilahti et al., 2007). A study in adults using magnetoencephalography (MEG; assessing spatiotemporal patterns of cortical activity) showed that the N1m (100-150 ms), the magnetoencephalography analogue of the N1, was larger to happy compared with sad prosody stimuli (Yagura et al., 2004). The sample size in this study, however, was small (N=6) and lateralisation effects on N1m latency were also present. Recent research has found that the N1 was not associated with emotional prosody recognition in adults (Spreckelmeyer, Kutas, Urbach, Altenmüller, & Münte, 2009).

5.2.2.2 The P2

Larger P2 amplitudes, at anterior (rather than posterior) sites, have been observed in response to angry and happy prosody in healthy adults (Paulmann & Kotz, 2008a), although other studies in healthy adults did not show emotional prosody effects on the P2 (Schirmer et al., 2005; Yagura et al., 2004). Recent research has shown that P2 (200 ms) amplitudes were reduced in response to happy voices when primed by happy voices in healthy adults (Spreckelmeyer et al., 2009). The P2 in adults has been found to be a marker of cross-modal integration between faces and voices with larger peaks for face-voice congruous than incongruous emotions (Balconi & Carrera, 2007). The P2 can also be a marker of detection of emotional prosody deviations in speech, for example, if the first half of a sentence was presented with neutral prosody and the second half with angry prosody (Chen, Zhao, Jiang, & Yang, 2011).

5.2.2.3 The N400

The N400 has received considerable attention in the vocal emotion processing literature. The N400 typically reflects semantic memory use in language comprehension (review by Kutas & Federmeier, 2000), with smaller amplitudes elicited by words which match a semantic context and are easier to process (i.e. bread with… 'butter') compared to those which do not (i.e. bread with…'socks') (Kutas & Hillyard, 1980, 1983). Smaller N400 amplitudes have also been observed to target words (i.e. success) which matched the preceding congruous (i.e. happy) compared to incongruous (i.e. sad) emotional prosody (Schirmer et al., 2002, 2005), suggesting that the N400 may be an index of emotional prosody perception and facilitating language processing (Schirmer & Kotz, 2003; Schirmer et al., 2002). Similarly, larger N400 (~300 ms) amplitudes have been found to deviant (contextually incongruous) emotional exclamations expressing 'woe' (i.e. Oh!) in passive oddball tasks using 'joy' as frequent stimuli (Bostanov & Kotchoubey, 2004). Recent research has confirmed that the N400 was elicited by sentences with violations of emotional and semantic content (Kotz & Paulmann, 2007; Paulmann & Kotz, 2008b). More recently it has been suggested that the N400 may be sensitive to the detection of a prosodic mismatch between a stimulus and its affective context (Kotchoubey et al., 2009).

5.2.2.4. The P3 and Slow Wave

A Positive Slow Wave (PSW: 600–1000 ms) was found to be modulated by emotional prosody in adults (Schirmer et al., 2005) and infants (Grossmann et al., 2005) and observed from 880 to 1500 ms during target detection in dichotic listening tasks with emotionally intoned nonsense syllables (i.e. ba) at parietal sites and over the right hemisphere (Erhan, Borod, Tenke, & Bruder, 1998). A late positive slow wave with a frontocentral distribution and duration of 150 ms was elicited by happy and sad emotional exclamations (Bostanov & Kotchoubey, 2004). The P300 was of equivalent amplitude for positive and negative voices in adults (Kotz & Paulmann, 2007) but larger (650-850 ms) to angry than happy voices in a group of children experiencing abuse compared to healthy controls (Shackman et al., 2007). Other studies, however, have not found an effect of vocal emotional expression on the P3 (250-400 ms) in adults (Yagura et al., 2004) and children experiencing abuse compared to typical children (Shackman et al., 2010).

5.3 The Neural Development of Emotion Processing and Child Psychopathology

5.3.1 Neural Markers of Non-Emotional Information Processing and Child Psychopathology

A substantial body of the ERP literature supports the suggestion that early sensory and perceptual processes may be impaired in children with hyperactivity (review by Barry, Johnstone, & Clarke, 2003). The section that follows reviews studies in children with hyperactivity in a generic sense and including studies of those with a clinical diagnosis of ADHD.

Studies have shown abnormalities in visual information processing in hyperactive children compared to controls (Brandeis et al., 1998; Jonkman et al., 1997a; van der Stelt, van der Molen, Gunning, & Kok, 2001), as reflected by reduced P3b component in visual selective attention tasks (Satterfield, Schell, Nicholas, & Backs, 1988; Satterfield, Schell, Nicholas, Satterfield, & Freese, 1990), longer latencies of P3a and P3b components in information processing tasks (Taylor, Voros, Logan, & Malone, 1993), and filtering deficits as early as 200 ms in visual colour selection tasks (Jonkman, Kenemans, Kemner, Verbaten, & van Engeland, 2004). The above evidence suggests that visual information processing may be impaired in hyperactive children. For example, reduced latencies of early components such as P2 at visual tasks in hyperactive individuals may be interpreted as reflecting rapid and atypical detection of stimuli linked to an impulsive style of visual information processing (Sunohara et al., 1999).

Deficits in auditory information processing are often reported in the literature. Studies using auditory selective attention tasks showed that hyperactive children presented reduced N1 (Loiselle, Stamm, Maitinsky, & Whipple, 1980; Satterfield, Schell, & Nicholas, 1994; Zambelli, Stamm, Maitinsky, & Loiselle, 1977) and parietal P3b (Jonkman et al., 1997a; Satterfield et al., 1990) amplitudes to target stimuli and larger P2 amplitudes to auditory stimuli (Oades, Dittmann-Balcar, Schepker, Eggers, & Zerbin, 1996; Winsberg, Javitt, Silipo, & Doneshka, 1993) compared to healthy controls. Deficits have been reported in both frontal and temporal lobes (Oades, 1998), including smaller P3 to target stimuli in frontal areas (Kilpelainen et al., 1999). Converging evidence derives from studies on gamma oscillations (Yordanova, Banaschewski, Kolev, Woerner, & Rothenberger, 2001) and effects of methylphenidate in enhancing presence of P3 (Schochat, Scheuer, & Andrade, 2002). It has been suggested that some of the above deficits may reflect more automatic and less controlled processing in hyperactive children (Oades et al., 1996). Auditory selective attention impairments in hyperactive children seem to be enhanced in those with CD comorbidity, as reflected by a reduction in mismatch negativity (MMN) in comorbid ADHD plus CD compared to healthy children

(Rothenberger et al., 2000). The above findings, taken together, indicate that automatic auditory processing may be impaired in children with hyperactivity.

Inconsistent findings in auditory information processing have also been reported in the literature. For example, early research did not reveal differences in amplitudes of N1, P2 (Satterfield et al., 1988) or P3b to non-attended stimuli (Loiselle et al., 1980) between hyperactive and healthy children. Only in recent studies have hyperactive children shown reduced P3b amplitudes to non-target auditory stimuli compared with controls (Jonkman et al., 1997a). The above inconsistencies indicate that more knowledge on the temporal course of auditory information processing is necessary. For instance, it is plausible that variations in latencies of early components (e.g. P2, N1c) can be a useful marker of the speed of early perceptual orienting to stimuli features, whereas alterations to late components (e.g. P3) may be an indicator for the timing in processing the response-relevant aspects of stimuli (review by Banaschewski & Brandeis, 2007).

Related ERP research in children with conduct problems is limited and few studies have examined subgroups of children with externalising behaviour problems (review by Patrick, 2008). Research has shown larger P3 amplitudes to warning stimuli in reaction time tasks in adult antisocial groups, suggested to reflect a heightened ability to attend to events of immediate interest (Raine & Venables, 1987). Larger N1 amplitudes and faster P3 latencies to warning stimuli in similar tasks have been found in male children at age 15 with related criminal behaviour at age 24 (Jutai & Hare, 1983; Raine, Venables, & Williams, 1990). Larger frontocentral negativities have also been found in psychopaths during processing of targets in auditory oddball tasks (Kiehl, Bates, Laurens, Hare, & Liddle, 2006). Other studies have shown significantly reduced P300 amplitude in oddball auditory tasks in impulsive aggressive adults (Gerstle, Mathias, & Stanford, 1998) and teenagers with higher levels of conduct problems (Bauer & Hesselbrock, 1999). Finally, a comorbid group of children with hyperactivity and conduct disorder were less impaired, compared to children with hyperactivity alone, at attentional orienting to visual stimuli as reflected by reduced P3a amplitudes (Banaschewski et al., 2003).

With regard to childhood anxiety, there is evidence that 10- to 14-year-old children with high compared to low trait anxiety presented longer temporal N1c latencies and greater N1c amplitudes to novel auditory stimuli in an oddball task, suggesting increased vigilance and behavioural inhibition to threatening situations involving novelty (Hogan, Butterfield, Phillips, & Hadwin, 2007). This study showed no effect of anxiety on the novelty auditory P3. Similarly, anxious 11-year-old children showed significantly larger NoGo-related N1 compared to non-anxious children on a Go/NoGo task, suggesting early attentional enhancement to stimuli indicating need for inhibition, but no group differences were found for P3 amplitudes (Baving, Rellum, Laucht, & Schmidt, 2004). Recent research has shown that high levels of behavioural inhibition during childhood and enhanced P3 amplitude to novelty in adolescence increased the risk for a history of anxiety disorders (Reeb-Sutherland et al., 2009).

5.3.2 Neural Markers of Emotional Information Processing and Child Psychopathology

5.3.2.1 Neural Markers of Emotion Processing and Hyperactivity

Despite evidence on the neural markers of processing non-emotional visual and auditory information, few studies have explored the ERP correlates of facial and vocal emotion processing, in particular, in children with behaviour problems.

Research on the electrophysiological correlates of emotion processing in children and adults with hyperactivity is at a very early stage (Herrmann et al., 2009; Williams et al., 2008). There is some preliminary evidence that impairments *do* exist in brain mechanisms during early perceptual analysis of facial emotion (Williams et al., 2008). The above study found reduced left occipital P120 followed by enhanced right occipital N170 and subsequent reduced left temporal P300 amplitude to anger during identification of facial expressions in 8- to 17-year-old adolescents with ADHD compared to control participants. The study also found delayed temporal P300 latency to anger bilaterally in the ADHD group. The authors suggested that reductions in P120 may indicate disturbances in the early visual-perceptual analysis of facial anger whereas enhancement of N170 amplitudes may suggest over processing of angry faces. Reduction of P3 was interpreted as reflecting flow-on difficulties with contextual processing of anger (Williams et al., 2008).

A second study has shown that adults with ADHD presented reduced occipital EPN (early posterior negativity; 170-300 ms), reflecting early sensory encoding of affective stimuli, in response to passive viewing of positive (but not negative) compared to neutral pictures (Herrmann et al., 2009). Similar research showed reduced attenuation of the startle response during the viewing of positive pictures in adults with ADHD compared to control participants (Conzelmann et al., 2009). Based on these findings, it was proposed that hyperactivity may be linked to reduced reactivity to rewards and positive stimuli (Herrmann, Biehl, Jacob, & Deckert, 2010), suggesting dysfunctions in the motivational-reward system (Sonuga-Barke, 2003).

Neuroimaging work has highlighted enhanced processing of anger in adolescents with ADHD. For example, a recent study reported enhanced activation in frontal and posterior cingulate regions during implicit processing of angry facial expressions in adolescents with ADHD compared to control participants (Marsh et al., 2008). Other studies have shown that ADHD adolescents presented decreased neural activity in the insula in response to negative pictures (Herpertz et al., 2008). A recent study found increased amygdala activity in adolescents with ADHD compared to controls when rating the subjective fear of faces (Brotman et al., 2010), however, research using an implicit processing task did not find any differences in amygdala activation to fearful facial expressions between adolescents with ADHD and controls (Marsh et al., 2008).

It should be highlighted that the above ERP findings have not been replicated and there is no related work looking at vocal emotional expressions, to indicate whether these effects are modality specific (face, voice). In addition, it is not clear whether deficits in facial emotion recognition generalise to younger children (the mean age in the study by Williams and colleagues was 14 years) to establish whether anger-related neural abnormalities change with development. Finally, it is not clear whether conduct problems would make a distinctive contribution to the above deficits.

5.3.2.2 Neural Markers of Emotion Processing and Conduct problems

No studies have been conducted to date on the ERP correlates of facial and vocal emotion processing in young children with conduct problems, although one study has shown that adult individuals with psychopathic tendencies showed less electro-cortical differentiation between emotional and neutral words (Williamson, Harpur, & Hare, 1991). The majority of studies have examined children with callous-unemotional traits who also have conduct problems or CD and have utilised fearful facial stimuli and neuroimaging methods (review by Sterzer & Stadler, 2009).

Neuroimaging research has identified reduced amygdala activations in response to fearful compared to neutral and angry faces in adolescents (Marsh et al., 2008) and children (Jones et al., 2009) with callous-unemotional traits. In addition, adolescents with conduct disorder displayed reduced amygdala activation to angry compared to neutral facial expressions than controls, although this effect was driven by a differential group response to neutral compared to angry faces (Passamonti et al., 2010). Individuals with conduct disorder also showed greater amygdala, temporal and prefrontal activation when viewing others in pain compared to no pain (Decety et al., 2009). The above findings suggest abnormal neural responses to distress cues in others (i.e. pain). This hypothesis is consistent with structural abnormalities in adolescents with conduct disorder (Sterzer, Stadler, Poustka, & Kleinschmidt, 2007). Reduced left amygdala activation to negative compared to neutral pictures has been found in adolescents with conduct disorder compared to control participants (Sterzer, Stadler, Krebs, Kleinschmidt, & Poustka, 2005). In contrast, other studies showed enhanced left amygdala activation in response to negative compared to neutral pictures during a passive viewing task in adolescents with conduct disorder compared to controls (Herpertz et al., 2008). Methodological differences, such as type of stimuli and task or the characteristics of the samples used (CD versus conduct problems and callous-unemotional traits) may account for discrepancies in the above findings.

In summary, existing research highlights the role of the amygdala in fear processing in individuals with psychopathic tendencies (review by Marsh & Blair, 2008). Beyond this evidence, however, the time course (ERPs) of anger processing in children with conduct problems across facial and vocal modalities remains unexplored.

5.3.2.3 Neural Markers of Emotion Processing and Anxiety

In regards to childhood anxiety, cognitive neuroscience techniques have only recently begun to be applied to the study of social information processing (Perez-Edgar & Bar-Haim, 2010). The evidence that is available has emphasised neural abnormalities in processing threat-related signals (i.e. anger) in developmental populations with anxiety. For example, adolescents with generalized anxiety disorders exhibited higher activation in the right prefrontal cortex compared to controls while viewing angry-neutral face pairs than neutral-neutral face pairs (Monk et al., 2008). Similarly, trait anxiety in children was associated with increased right prefrontal cortex activation to angry faces, suggested to reflect attention bias towards angry faces (Telzer et al., 2008). Support for an anger bias in childhood anxiety has been provided by other imaging studies (Brotman et al., 2010; Roy et al., 2008).

Findings are consistent with the adult ERP literature showing increased P1 amplitudes towards targets in the same location as angry faces in dot-probe tasks (Santesso et al., 2008) and larger occipitotemporal N170 amplitudes to angry faces in socially anxious patients (Rossignol & Campanella, 2008). Similarly, threat-related faces elicited faster latencies and greater amplitudes of early ERPs in high-anxious compared to low-anxious adults (Bar-Haim, Lamy, & Glickman, 2005). Other studies have not found P3 amplitude differences in anxious participants between different types of emotional faces (Tempesta et al., 2008) or modulation of the N170 by emotional expression (angry, happy) of the face (Santesso et al., 2008). In summary, existing ERP research has focused on adult populations and facial stimuli and little is known on the time course of anger processing in children with anxiety using vocal stimuli.

5.3.2.4. The Role of Anger Processing in Child Psychopathology

The existing literature in developmental populations with externalising (Williams et al., 2008) and internalising (Monk et al., 2006; Monk et al., 2008) problems highlights anger-related neural abnormalities. This is consistent with clinical (Down, Willner, Watts, & Griffiths, 2011) and empirical (Zeman, Shipman, & Suveg, 2002) work. Accurate identification of anger is critical in learning what is socially appropriate. Learning to recognise and regulate anger often represents a difficult developmental task for children (Kopp, 1989).

Difficulty in regulating anger has often been associated with behaviour problems in children (Eisenberg et al., 1997; Eisenberg et al., 2000; Frick & Morris, 2004). Children with hyperactivity presented difficulties in the recognition of anger from facial expressions (Da Fonseca et al., 2009; Kats-Gold et al., 2007; Yuill & Lyon, 2007). Children with hyperactivity comorbid with anxiety showed difficulties in recognising anger from vocal expressions (Manassis, Tannock, & Barbosa, 2000). In addition, externalising symptoms in children have been associated with higher bias to anger from facial expressions (Barth & Bastiani, 1997). Adults with hyperactivity expressed anger in more dysfunctional ways, such as noisy arguing, physical or verbal assaults (Ramirez et al., 1997; Wender, 1995) and showed a number of deficits in the recognition of anger from facial expressions (Friedman et al., 2003; Rapport et al., 2002).

Deficits related to recognition of positive (i.e. happy) expressions have also been reported in children (Sinzig et al., 2008) and adults (Herrmann et al., 2009; Rapport et al., 2002) with externalising symptoms. It is therefore important to include positive (i.e. happy) as well as angry expressions in future ERP studies to serve as comparison conditions against which to evaluate responses to angry expressions. Future investigations should examine alternative emotion processing indices in order to evaluate the specificity of anger related processing to child psychopathology.

In light of the above evidence emphasising the role of anger in child psychopathology, the following ERP studies aimed to investigate the neural mechanisms of vocal (Study 4) and facial (Study 5) processing with a specific focus on anger processing.

Recent research suggests that not only neural systems become more specialised with development but they also are sensitive to environmental stimulation (Frith & Frith, 2010; Panksepp & Smith-Pasqualini, 2005). Face recognition reflects an experience-expectant process, whereby perceptual and cortical specialisation is influenced by exposure to faces during sensitive periods in development (Johnson, 2001; Morton & Johnson, 1991; Nelson, 2001). Empirical evidence for the role of early experience in the neural development of facial emotion processing derives from studies of institutionalised infants. For example, institutionalised infants showed smaller P1 and N170 amplitudes and longer latencies to facial expressions of emotion, reflecting a more impaired style of processing, compared to never institutionalised infants (Moulson et al., 2009; Zeanah et al., 2003).

The above findings have not been replicated in relation to vocal emotion processing. In addition, previous research has not explored directly the role of parent characteristics, such as internalising and externalising psychopathology, in children's neural responses to facial and vocal expressions of emotion.

There is some preliminary evidence that differences in the frequency that mothers experience negative emotions can influence their offspring's neural responsivity to facial emotion. For example, maternal negative affect was associated with 7-month-infants' greater attentional orienting, as reflected by larger Nc amplitudes to fearful than happy expressions (de Haan et al., 2004). Externalising parental psychopathology has less often been studied in relation to children's neural processing of emotional stimuli. Although adults with externalising symptoms often display higher state and trait anger (Ramirez et al., 1997), the impact of adult vocal anger on children's ERPs has not been explored so far. There is some preliminary evidence that children experiencing physical abuse devoted more cognitive resources, as indexed by higher P3a amplitudes, toward processing vocal anger compared to non-abused children (Shackman et al., 2007), suggesting that exposure to parental anger may alter patterns of neural anger processing in children.

These questions provide an excellent platform of opportunity to explore whether parent characteristics can influence children's neural responses to emotional stimuli.

Chapter 6. Methods for Study 4 and Study 5

The two ERP studies adopted similar methodologies as participants were recruited to a single experimental session. The methods of the two ERP studies will be discussed in this chapter and details specific to each study will be presented in their respective chapters.

6.1 Participants

The same sample of 80 children from the community participated in the two ERP studies. This was a different sample from that used in the previous studies. Teachers and clinicians were asked to recommend for the study children with normal hearing and vision and no history of neurological disorders based on school and clinical records. Twenty-six children were approached through clinical services on the basis of an enriched sampling strategy. From those, 8 children participated and only 6 produced complete data.

Complete behavioural data were available from 70 children in Study 4 (mean age= 8.80 years, SD=1.66, age range 6.00-11.83, 45 boys) and 73 children in Study 5 (mean age= 8.68 years, SD=1.72, age range 5.42-11.83, 48 boys). Children with a mean of correct and artifact free trials lower than a set criterion of 20 trials for at least one of the three conditions were excluded from ERP analyses in each study (see Section 6.7 and Appendix C). ERP data were available from 60 children in Study 4 (mean age= 9.02 years, SD=1.63, age range 5.75-11.83, 44 boys) and 63 children in Study 5 (mean age= 8.89, SD=1.69, age range 5.42-11.83, 42 boys). Children's mothers (mean age=39.53 years, SD=5.46) also participated. Pilot data from 5 children (mean age= 7.30 years, SD=.73, age range 6.08-8 years, 2 boys) were excluded form analyses due to incomplete data and artifacts. One boy (5.42 years) with a hearing threshold in the atypical range (46 dB) in the right ear (see section 6.5) was excluded from the analyses in Study 4.

6.2 Sample Characteristics

The ERP studies followed a dimensional approach to child and parent psychopathology. The proportion of participants in the atypical range for symptoms was also examined based on the recommended cut-off points (see section 3.3.5). Because hyperactivity scales (SDQ and WWP) were highly correlated ($r=.78$, $p<.001$) in both ERP studies, standardised values of the two measures were combined. Similarly, because temperamental anger (Child Behavioural Questionnaire) and conduct problems (SDQ) were highly correlated ($r=.42$, $p<.001$) in both studies, standardised values of these measures were also combined. Tables

6.1 and 6.2 present means and standard deviations for symptoms and the percent of participants in the atypical range.

Table 6. 1. *Means (SD) for child symptoms and percent of children in the atypical range for symptoms in the whole sample (N=73)*

	Mean	SD	% atypical
SDQ			
Hyperactivity	3.64	2.75	20.5%
Conduct problems	1.95	2.67	26%
Emotional problems	2.19	2.26	26%
Peers problems	2.01	2.20	-
Pro-social behaviour	7.78	2.05	-
WWP			
Hyperactivity	10.50	11.82	15.1%
DOMINIC			
Generalized Anxiety	5.02	2.92	15.2%
Depression	5.59	3.58	23.3%
CBQ			
Temperamental Anger	2.99	.94	-
ERC			
Emotion Dysregulation	1.80	.53	-

SDQ=Strengths and Difficulties Questionnaire, WWP=Werry Weiss Peters Activity Scales, ERC=Emotion Regulation Checklist, DOMINIC=Anxiety/ Depression picture based interview, CBQ=Children's Behaviour Questionnaire.

Table 6. 2. *Means (SD) for parent characteristics and percent of parents in the atypical range for symptoms in the whole sample (N=73).*

	Mean	SD	% atypical
GHQ			
Depression	1.45	2.42	29.6%
ADHD–CBS			
Inattentive	3.59	2.65	25.4%
Hyperactive	3.61	2.40	19.7%
Combined	7.21	4.52	-
PSOC			
Satisfaction	33.02	5.32	-
Self-Efficacy	24.83	3.47	-
Total PSOC	57.87	7.06	-

GHQ=General Health Questionnaire, ADHD-CBS=ADHD-Current Behaviour Scale, PSOC=Parenting Sense of Competence

6.3 Materials

6.3.1 Facial expression stimuli

The stimuli employed in the ERP studies, were identical to those in Study 3 (see section 4.3.3.2). Stimuli consisted of angry and happy facial expressions plus a neutral expression displayed by a female actress. The rationale for the selection of angry and happy stimuli is explained in section 5.3.2.4. The ERP studies did not include sad stimuli because sad stimuli did not work well with children in Study 2 and Study 3. The ERP studies adopted obvious (100% intensity) facial stimuli because the aim was to maximise correct responses and the number of correct and artefact-free epochs for ERP analyses.

6.3.2 Vocal expression stimuli

The ERP studies employed the same vocal stimuli used in Study 3 (Maurage et al., 2007). Vocal stimuli corresponded to the emotions of anger and happiness at a high (100%) intensity plus a neutral expression for consistency with the facial stimuli. All vocal stimuli were standardised as for acoustic parameters including mean intensity (76 dB) leading to a correspondent SPL of 0.13 Pa., duration (700 ms), recording frequency (1600 Hz), and rise and fall ramp times (20 ms). Acoustic analyses were conducted using Praat sound-analysis software (Boersma & Weenink, 2009). Results are presented in Table 6.3.

Table 6. 3. *Duration, fundamental frequency -f0 (in Hz) and intensity (in dB) values from acoustic analyses carried out for the vocal stimuli.*

Emotion	Duration	Mean f0	Min f0	Max f0	Mean dB	Min dB	Max dB
Angry	700 ms	294.85	79.07	355.74	76.85	63.43	81.92
Happy	700 ms	350.31	221.59	525.85	76.50	68.36	83.42
Neutral	700 ms	191.30	181.21	194.54	76.34	70.30	78.31

6.4 Task Design

Children took part in two tasks: i) a vocal emotional expression and ii) a facial emotional expression identification task with tasks counterbalanced in order across participants. The experiment consisted of a three choice emotion identification task with three response options (angry, happy and neutral/ 'ok'). Each task (voice/face) corresponded to each ERP study and consisted of 180 experimental trials (60 trials per emotion type) presented in two blocks of 90 trials each. There was a 5-minute rest break in between the two blocks. Children participated in 12 practice trials (four presentations of each emotion) at the beginning of each task. Children were given clear instructions about the response options and did not receive feedback about their performance accuracy. Children took part in the second task (i.e. either face or voice) after completion of the first task. The following instructions were given to the children before the practice block of each task:

'You are going to see some faces/hear some voices. You need to identify the emotion in the face/voice and press one of the three keyboard buttons with the labels 'angry', 'happy' or 'okay' to indicate your response. Try to respond as accurately as you can. In between each face/voice you will see a small cross on the centre of the screen. Please look at this throughout the task. If you don't understand the instructions, ask the experimenter now'

After checking that the participants had understood the instructions, participants continued on to the practice trials and the main experimental block. Button press responses were logged on the computer via Presentation software (version 10.0). Each trial began with the presentation of a central fixation cross (500 ms) followed by the presentation of the stimulus (1000 ms in the case of facial expressions; 700 ms in the case of vocal expressions) followed by a blank screen until the participants gave a response and a 1000 ms inter-trial interval (ITI). Stimulus presentation was randomised across participants. Facial expressions were displayed on a computer monitor. Vocal expressions were presented binaurally via supra-aural headphones.

6.5 Pure Tone Audiometric Assessment

Audiometric testing was conducted with a standard clinical audiometer in order to establish whether participants' hearing threshold was within the average range, adopting a threshold of 25 dB at a range of frequencies following the British Society of Audiology Recommended Procedures (2004). The following instructions were given to the children verbatim before testing:

"I am going to test your hearing by measuring the quietest sounds that you can hear. As soon as you hear a sound (tone), press the button. Keep it pressed for as long as you hear the sound, no matter which ear you hear it in. Release the button as soon as you think you no longer hear the sound. Whatever the sound, and no matter how faint the sound, press the button as soon as you think you hear it, and release it as soon as you think it stops."

After checking that the participants had understood the instructions, participants were instructed to maintain their gaze in a direction opposite the audiometer device throughout testing. Participants' response to the test tone (as signalled by a red light on the audiometer device) indicated when the test tone was heard and when it was no longer heard. Tones were presented to children via a pair of Telephonics TDH-39P earphones, starting at a frequency of 1000 Hz, followed by 1500 and 500 Hz. The duration of the presented tone and the interval between the tones varied between 1 and 3 sec ensuring the timing of each tone was not predictable. The hearing threshold was obtained following the recommended procedure of the British Society of Audiology (2004): Starting from 30 dB, following a satisfactory positive response the level of the tone was reduced in 10 dB steps (i.e. 30, 20 and 10 dB) until no further response occurred. Subsequently, the level of tone was increased in 5 dB steps until a response occurred. After the response, the level was again decreased by 10 dB, thus beginning another ascending 5 dB series until the participant responded again. Each participant's threshold was defined as the lowest level at which responses occurred in at least half of a series of ascending trials with a minimum of two responses required at that level. This procedure was repeated for each ear (Right/Left) and for each of the three frequency levels (1000, 1500, 500Hz) separately. An average of the thresholds from the three frequencies was derived in each ear.

6.6 Child and Parent Measures of Psychopathology

6.6.1 Parent-rated Measures of Child Behaviour

6.6.1.1 Strengths and Difficulties Questionnaire (SDQ)

A detailed description of this questionnaire is provided in section 3.3.5.1.1. In the present study a dimensional approach was adopted for all questionnaire measures with higher scores reflecting higher child symptoms.

6.6.1.2 Werry Weiss Peters Activity questionnaire (WWP)

The WWP was also used to gain further information regarding hyperactive symptoms in children (see section 3.3.5.1.2).

6.6.1.3 Emotion Regulation Checklist (ERC)

The ERC was used to assess emotion regulation and dysregulation (see section 3.3.5.1.3).

6.6.1.4 Children's Behaviour Questionnaire (CBQ)

This is a well validated questionnaire assessing temperamental dispositions in 7- to 10-year-old children (Putman & Rothbart, 2006). Parents were asked to rate their child on a 5-point scale ranging from 1 (almost always untrue) to 5 (almost always true). Parents were also provided with a Non Applicable response option when the child had not been observed in the situation described. The standard form of the questionnaire consists of 38 items assessing anger, fear, sadness, shyness and attention focusing. Exemplar items include 'child gets angry when s/he has trouble with a task'. The scale score is created by averaging applicable item scores. The 'anger/frustration' scale (7 items) of the questionnaire was used for the purposes of the present study. Alpha coefficients are .76. In the ERP studies alpha was satisfactory at a=.87.

6.6.2 Self-report Measures of Child Behaviour

6.6.2.1 The DOMINIC Pictorial Interview

The DOMINIC (Valla, Bergeron, & Smolla, 2000) is a DSM-IV based pictorial interview designed to assess a range of psychiatric symptoms in 6- to 11-year-old children. The DOMINIC depicts a child named 'Dominic' facing situations in the daily life of children. Items are presented in the form of an interview via pictures accompanied by questions read to the children verbatim (i.e. do you often feel like crying?) and require a 'yes/no' answer. 'Yes' answers are assigned a score of 1 whereas 'No' answers a score of zero. The pictures illustrate the emotional and behavioural content of the DSM-IV Axis I symptomatology. For this study, the Generalized Anxiety (14 items) and Depression (18 items) scales were used measuring tendencies towards anxiety and depression respectively. 8 items were anxiety specific, 12 items were depression specific and 6 items overlapped between anxiety and depression scales (Valla, 2000). Test-retest reliability for the DOMINIC is satisfactory with Kappa ranging from .40 to .69. Cronbach's Alpha for internal consistency was .83 for the Depression scale and .66 for the Anxiety Scale (Valla et al., 2000). In the ERP studies alpha was .74 for both scales. Scores can be used both categorically and continuously. In the present studies higher scores reflected higher tendencies toward anxiety and depression. The proportion of children who fell in the atypical range of symptoms was also explored using the recommended cut-offs of 9 out of 14 symptoms for anxiety and 9 out of 18 symptoms for depression (Valla et al., 2000).

6.6.3 Self-report Measures of Parent Characteristics

6.6.3.1 Attention Deficit Hyperactivity Disorder Current Behaviour Scale

This scale consists of 18 items derived from the 18 ADHD symptom DSM-IV criteria for adults (see section 3.3.5.2.1).

6.6.3.2 General Health Questionnaire-(GHQ)

The present questionnaire is a self-report measure of depressive symptoms in adults (see section 3.3.5.2.2).

6.6.3.3 Parenting Sense of Competence (PSOC)

This questionnaire assessing attitudes and feelings related to parenting (see section 3.3.5.2.3).

6.7 ERP Methods

6.7.1 Electrophysiological Recording

EEG data were recorded from an electrode cap (Easycap, Herrsching, Germany) containing 66 equidistant silver/silver chloride (Ag/AgCl) electrodes using Neuroscan Synamps^2 70 channel EEG system. Cap electrodes were referenced to the nose. The EEG data were sampled at 250 Hz with a band pass filter at 0.1 to 70 Hz using an AC procedure and recorded from 30 sites (1, 2, 4, 6, 8, 10, 12, 13, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 33, 35, 37, 38, 39, 40, 42, 44, 46, 47, 53 and 54). Analyses focused on 19 sites at central, parietal, occipital and temporal areas (please refer to Figure 7.2). Selection of these sites was literature informed and aimed at maximising the number of artifact-free epochs. A ground electrode was fitted midway between the electrode at the vertex and frontal site 32.

Vertical electro-oculogram (vEOG) was recorded from four electrodes: two bipolar electrodes were placed directly beneath the left and right eyes and affixed with tape, while the two electrodes placed above the right and left eye were included within the electrode cap. Impedances for vEOG, reference and cap electrodes were kept below 5 kΩ.

6.7.2 ERP Epoching

The ERP epoch was defined as 100 ms pre-stimulus to 1000 ms post-stimulus. Each epoch had a baseline of 100 ms of pre-stimulus activity and was filtered with a low-pass filter down 48 dB at 32 Hz. An ocular artifact reduction procedure (Semlitsch, Anderer, Schuster, & Presslich, 1986) based on vEOG activity was used to remove the influence of blink and other eye movement; epochs were rejected if amplitudes exceeded ±150 μV in any EOG or scalp site included in analyses or if participants responded incorrectly. Average ERPs were calculated for each emotion type (Angry, Happy, Neutral). A minimum of 20 artifact free epochs out of a total of 60 epochs for each of the three emotion types per participant were used for calculating ERP averages. ERP analyses were conducted with Neuroscan 4.3 software.

6.8 Procedure

Participation in the ERP studies was by informed written consent of parents and assent of children approached through primary schools and clinical services. Ethical approval was granted by the Ethics Committee, School of Psychology, University of Southampton Research Governance Office and NHS Southampton Research Ethics Committee A for the purposes of recruitment of children from clinical services. It was emphasised that participants could withdraw their participation at any time without any unfavourable consequences. Children took part in the experimental task in the laboratory while parents filled in the questionnaires. Children were encouraged to keep as still as possible and to keep eye movements to a minimum throughout the experimental procedure. Participants received letters of debriefing on the findings of the studies upon completion of the studies.

Chapter 7. Study 4. The Electrophysiological Correlates of Vocal Anger Processing in Children and Links to Behaviour Problems

7.1 Introduction

Following validation of emotional prosody stimuli in Study 3, these stimuli were employed in Study 4 to examine the electrophysiological correlates of vocal anger processing in children. ERP methods provide a useful platform on which to attempt to dissociate deficits in early attention processing and emotion-specific processing (Herba & Phillips, 2004).

First, the present study aimed to investigate the neural correlates of vocal anger processing in typically developing 6- to 11-year-old children. Recent research suggests that cerebral voice processing is well-established early in development. Voice sensitivity emerges between 4 and 7 months in the posterior temporal cortex (Grossmann et al., 2010). A frontotemporal positive component (~100 ms), specific to vocal compared to non-vocal sounds, has been found in preschool (Rogier et al., 2010) and 4- to 8-year-old (Bruneau et al., 1997) children. In addition, enhanced sensory processing of emotional (angry, happy) compared to neutral prosody has been shown in 7-month-old infants, as reflected by a more positive slow wave (500 ms) elicited by angry and happy compared to neutral prosody at temporal sites (Grossmann et al., 2005). Research has suggested greater allocation of attention to threatening (i.e. angry) vocal signals in infants, in terms of a more negative frontocentral component (450 ms) elicited by words spoken with angry compared to happy and neutral prosody (Grossmann et al., 2005).

The pattern of findings reported above is comparable to the one observed in the adult literature of voice processing (Charest et al., 2009) and vocal emotion processing (Grandjean et al., 2005). In addition, voice sensitivity and modulation of brain activation by affective content has been found to be larger in the right compared to the left hemisphere in both the infant (Grossmann et al., 2010) and adult (Belin et al., 2000; Ethofer et al., 2006) literature. However, the above studies have focused on infants and adults. Little is known regarding the neural responses to emotional prosody in typically developing school-aged children. Existing studies have employed linguistic stimuli in a small sample of children (Korpilahti et al., 2007; Shackman et al., 2007). This is a limitation in the developmental literature this study aimed to address.

A second aim of the present study was to investigate links between ERPs to vocal anger and child psychopathology, grounded on recent evidence highlighting the role of neural abnormalities during vocal anger processing in children's atypical development.

A recent study investigated the neural correlates of vocal anger processing in fourteen 9- to 12-year-old boys with Aspergers syndrome (AS) and 13 controls (Korpilahti et al., 2007). Although the study did not report a differential neural response to the two emotion conditions employed (angry/happy) in any group, children with AS showed an impaired style of processing affective prosody relative to controls. In particular, the N1 peaked later in children with AS (150 ms) compared to controls (137 ms) in centrotemporal areas of the right hemisphere (Korpilahti et al., 2007). In addition, the late mismatch negativity (MMN) latency, reflecting higher-order integrative processes in auditory perception (Cheour, Leppänen, & Kraus, 2000), was shorter in children with Aspergers (612 ms) compared to controls (648 ms). The above study provides some preliminary evidence that abnormal development of the neural substrates supporting emotional prosody perception may increase children's risk for an atypical developmental trajectory (i.e. Aspergers syndrome). Processing of emotionally salient stimuli has been suggested to be critical in the pathogenesis of other childhood psychiatric conditions such as autism (Johnson et al., 2005; Dawson et al., 2004).

This hypothesis has not yet been explored in children with externalising symptoms. This is surprising given the behavioural evidence that these children were less accurate at recognising negative facial (Blair et al., 2005) and vocal (Stevens et al., 2001) expressions and displayed a selective perceptual bias to vocal anger in particular (Manassis et al., 2007). Children with behaviour problems presented difficulty in regulating anger (Eisenberg et al., 2001) and deficits in recognising anger from non-verbal cues (Kats-Gold et al., 2007; Pelc et al., 2006), which persisted into adulthood (Rapport et al., 2002). Comorbidity with anxiety seemed to amplify vocal anger processing deficits in children with externalising symptoms (Manassis et al., 2000). ERP methods, because of their high temporal resolution, can be particularly useful in elucidating the stages of vocal anger processing as they unfold in time and identify early markers of possible deficits or biases.

A recent study has suggested anger-related neural abnormalities in processing facial emotional expressions in adolescents with ADHD compared to healthy controls (Williams et al., 2008), however, these findings have not been replicated with vocal expressions in younger children with ADHD symptoms. In addition, it is not clear, from the existing literature, whether externalising symptoms are associated with a pattern of heightened or reduced sensitivity to anger (Williams et al., 2008) and how this relates to different comorbid conditions, such as hyperactivity and conduct problems. As different emotion processing mechanisms may characterise different psychopathological profiles, it is important to study children with hyperactivity and conduct problems separately (Cadesky et al., 2000). Finally, in view of recent neuroimaging work (Monk et al., 2008; Roy et al.,

2008) supporting abnormal neural processing of anger-related cues in children with anxiety, it is important to disentangle internalising and externalising aspects of problem child behaviour and separately examine the neural mechanisms of vocal anger processing in each psychopathological condition.

A third, supplementary aim of the present study was to explore the role of parent characteristics in children's neural processing of vocal anger. Recent ERP evidence suggests that early trauma may contribute to the development of atypical neural responses to processing angry voices. For example, Shackman and colleagues (2007) examined vocal anger processing in physically abused and non-abused 7- to 12-year-olds and showed that when children were instructed to attend to vocal expressions of emotion, abused children presented amplified attention, reflected by larger P3 amplitude, to vocal anger compared to non-abused children, independently of voice familiarity (i.e. mother, stranger). In addition, the relationship between physical abuse and child anxiety was explained by children's amplified attention (as reflected by enhanced P3 amplitude) to angry voices (Shackman & Pollak, 2007). Social interactions in antisocial parent-child dyads are often characterised by hostility and anger (Frick & Morris, 2004). It is possible that amplified attention (P3) to vocal anger may be present in children of parents with externalising symptoms. It is therefore, important from a developmental psychopathology perspective to explore the origins of children's anger processing in a family context. Understanding the pathophysiology of anger perception in children with behaviour problems and its relationship with the family context can have important implications for parenting and clinical practices.

In summary, given the prominent role of anger processing in the existing literature the present study adopted a special focus on vocal anger processing.

7.2 Aims

The aims of the present study were as follows:

1. To examine the neural correlates of vocal anger processing in typically developing 6- to 11-year-old children from the community.

2. To explore associations between neural markers of vocal anger processing and child externalising and internalising symptoms.

3. To explore the role of parental psychopathology in children's neural processing of vocal anger.

A mean amplitude method for selected time windows was judged most suitable for the aims of the present study. This method has been used in similar research with vocal emotional expressions in school-aged children (Shackman et al., 2007).

For the purposes of the present analyses a mean amplitude method was followed for the following components: N100 (90-180 ms), P2 (180-270 ms), P3 (270-360 ms), N400 (380-500 ms) and the Slow Wave (520-720 ms). The above time windows were selected because they best captured each ERP component identified by visual inspection of the ERP averages across central, parietal, occipital temporoparietal sites. Selection of these components was consistent with recent literature on vocal emotion processing (see section 5.2.2). Figure 7.1 illustrates the targeted ERP components in this study.

Analyses focused on 19 electrode sites (see Figure 7.2) with equal distribution across central, parietal, occipital, and temporoparietal scalp areas. Mean amplitude was initially calculated for each individual site and subsequently the mean amplitude for each of the ERP components was calculated as a combined score for a number of defined groups of electrode sites (hence forth termed ‘ scalp regions’), in order to increase the reliability of measurement. Regional analyses present a number of advantages over single site-based analyses (Dien & Santuzzi, 2005). Selection of electrode groups was based on the strong statistical similarity of the grand average ERPs for each electrode. The grand ERP averages for individual electrode sites are available in Appendix D. The first group of electrodes sites comprised the ‘central region’ and included sites 1, 2, 4, 6, 10 and 16 (see Figure 7.2). The ‘parietal region’ included sites 12, 13, 14, 24 and 26. The ‘occipital’ region included electrode sites 37, 38, 39 and 40. A final ‘temporoparietal region’ included sites 22, 47, 28 and 53. Correlations between ERP waveforms within each of the above regions were statistically stronger (more significant) (Pearson’s r= from .63 to .95, $p<.001$) compared to correlations between amplitudes of electrode sites belonging to different regions (Pearson’s r= from .25 to .64, $p<.01$).

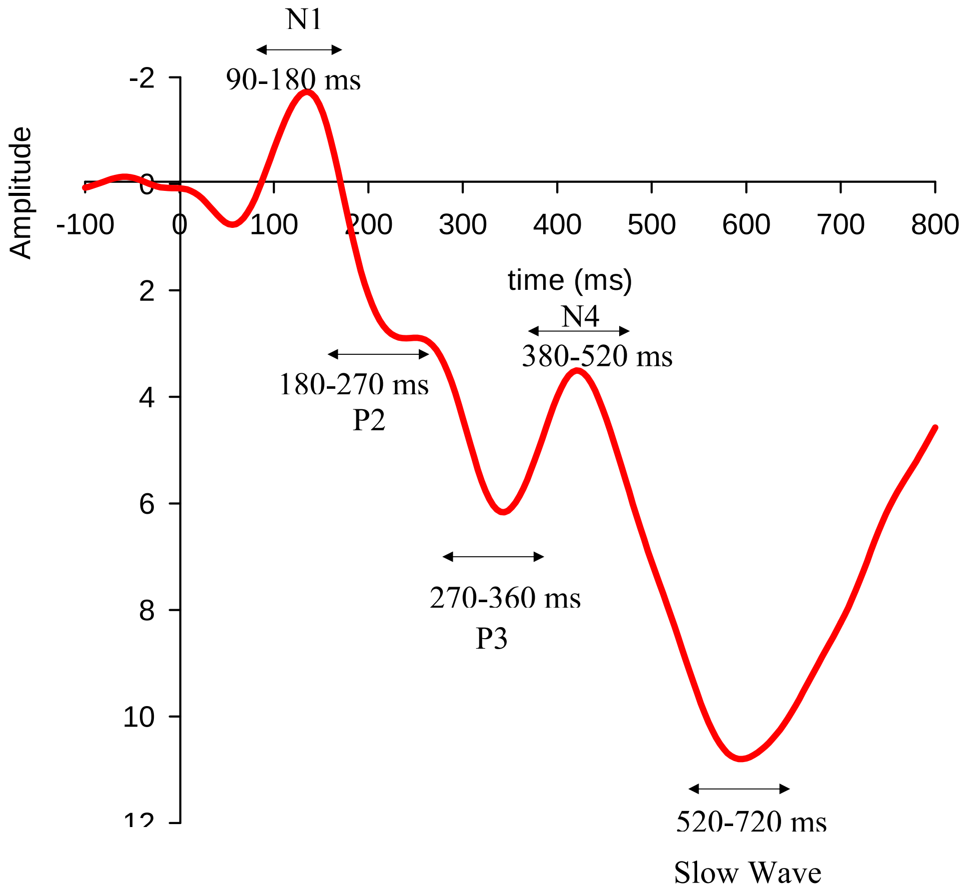


Figure 7. 1. Grand average ERP across emotions (angry, happy and neutral) in parietal region illustrating the targeted ERP components to voices. Scale is -2 to + 12 µV.

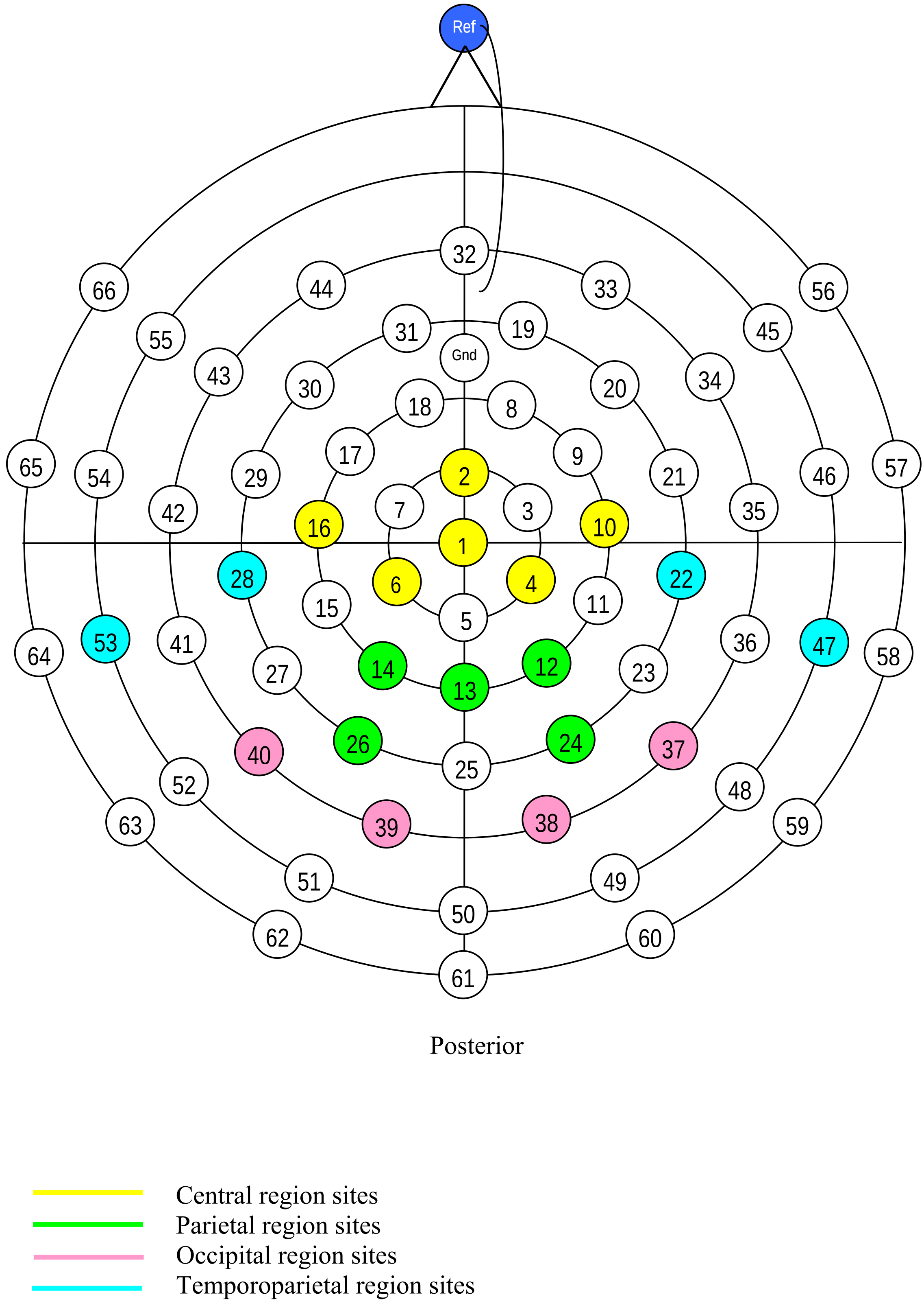


Figure 7. 2. Montage with 19 sites used in EEG recording and sites per region in Study 4

7.4 Results

7.4.1 Performance

Following data processing, conducted as specified in Section 3.4, initial analyses aimed to explore the general performance levels of discrimination accuracy and response bias.

7.4.1.1 Initial data treatment

Kolmogorov-Smirnov test indicated that values of discrimination accuracy were significantly different from normality (p<.001). Values for response bias did not differ significantly from normality (Angry: z=1.07, p=.197, Happy: z=1.04, p=.230) except for bias to neutral (z=2.09, p<.001). Because values were not normally distributed due to ceiling effects, and could not be transformed non-parametric tests were used[4].

7.4.1.2 Emotion processing measures and child hearing, age and gender

A mean hearing threshold was created by combining the hearing threshold from the right and left ear because the two were highly associated (r=.61 p<.001). Non-parametric Spearman's correlations showed that children's mean hearing threshold was not significantly associated with accuracy for angry or happy voices (p >.05) and marginally associated with accuracy for neutral voices (r_s =-.25, p=.040).

Spearman's correlations showed that child age was not associated with accuracy for angry, happy or neutral voices (p >.05). Similarly, child age was not significantly associated with response bias to angry, happy or neutral (al p's >.05). Mann-Whitney U tests showed a significant difference in accuracy between boys and girls for angry (U=317.00, z=-3.01, p=.003, r=-.36) and neutral (U=370.500, z=-2.35, p=.019, r=-.28) but not happy (U=430.00, z=-1.62, p=.104, r=-.19) voices. Boys were significantly more accurate for angry and neutral voices than girls (see Table 7.1). Also, Mann-Whitney U tests showed a significant difference in bias between boys and girls for happy (U=391.000, z=-2.10, p=.035, r=-.25) but not angry (U=460.00, z=-1.26, p=.208, r=.-.15) or neutral (U=487.500, z=-.92, p=.358, r=-.11). Girls presented significantly higher bias to happy voices compared to boys (see Table 7.1). Parametric and non-parametric tests for bias produced similar results. Because boys outnumbered girls in this study, gender differences need to be treated with caution.

[4] Effect sizes are reported as 'r equivalent'.

7.4.1.3 Discrimination accuracy and response bias overall performance

The effect of emotion type on accuracy was examined. Values of discrimination accuracy were entered in repeated measures non-parametric Friedman's ANOVA with emotion (Angry, Happy and Neutral) as within-subject factor. Results showed a significant effect of emotion type on accuracy (x^2 (2) =18.83, p<.001). Wilcoxon tests were used to follow up this finding. Non-parametric paired Wilcoxon tests compared angry to happy, angry to neutral and happy to neutral. A Bonferroni correction was applied, so all effects were reported at a .05/3=.016 level of significance. Results showed that accuracy was significantly higher for angry compared to neutral voices (T=478.50, p<.001, r=-.52) but there was no significant difference in accuracy between happy and neutral (T=755.50, p=.025, r=-.26) and between angry and happy (T=919.00, p=.169, r=-.16) voices. The effect of emotion type on bias was examined via repeated measures ANOVA because bias values were normally distributed. Results showed a significant effect of emotion on response bias (F (2,138) =6.50, p=.002, η^2_p =.09). Pair-wise comparisons indicated that participants displayed significantly higher bias to neutral compared to happy (p=.014) but the difference between angry and happy or angry and neutral was not statistically significant (p >.05). Means, medians and standard deviations of accuracy and bias values are presented in Table 7.1.

Table 7. 1. *Mean, median and SD for discrimination accuracy and response bias to vocal expressions in the whole sample and by gender.*

Vocal Expression	Discrimination Accuracy			Response Bias		
	Boys	Girls	Total	Boys	Girls	Total
Angry						
Mean	.90	.70	.83	.36	.33	.35
Median	.95	.87	.90	.34	.24	.33
SD	.10	.32	.27	.17	.23	.20
Happy						
Mean	.86	.73	.82	.25	.36	.29
Median	.92	.86	.91	.19	.33	.26
SD	.15	.33	.24	.16	.22	.19
Neutral						
Mean	.85	.63	.77	.59	.46	.54
Median	.92	.80	.88	.34	.26	.34
SD	.14	.38	.28	.70	.50	.64

Note: Accuracy values range: -1≈ worse than chance, 0 ≈ chance, 1≈ better than chance. Response bias values range from 0 -1. Absence of bias ≈ 0, Presence of bias ≈ 1.

7.4.1.4 Correct classifications and misattribution patterns

Further analyses examined correct classifications and misattribution patterns (i.e. tendency to confuse an expression with another) for angry, happy and neutral vocal expressions. Children had little difficulty in identifying the vocal emotional expressions suggesting that for the purposes of the ERP study, the emotion identification task worked well. Mean accuracy for all three vocal expressions was 87.16% (SD=15.72%). Friedman's ANOVA indicated a significant difference between the percent of angry voices classified as neutral and the percent of happy voices classified as neutral (x^2 (1) =17.85, p<.001). Happy compared to angry voices were more likely to be classified as neutral (T=408.00, p<.001, r=-.46). Mean percent of trials classified correctly and misattributions are summarised in Table 7.2.

Table 7. 2 *Mean percent (SD) of trials classified correctly and misattributions.*

	Child Response		
Vocal Expression	Angry	Happy	Neutral
Angry	**89.38(15.67)**	3.54(6.60)	5.33(10.55)
Happy	4.00(9.05)	**87.28(17.45)**	8.09(12.02)
Neutral	6.80(14.62)	6.19(13.85)	**84.83(21.71)**

Note: In bold the vocal expressions classified correctly.

7.4.1.5 Intercorrelations between emotion processing measures

Table 7.3 presents the non-parametric Spearman's inter correlations between the emotion recognition accuracy and response bias measures. Accuracy scores to angry, happy and neutral voices were positively associated; however, response bias scores were negatively associated with each other.

Table 7. 3 *Spearman's correlations (p value) for the emotion processing measures*

	Accuracy Angry	Accuracy Happy	Accuracy Neutral	Bias Angry	Bias Happy	Bias Neutral
Accuracy Angry						
Accuracy Happy	**.73(.001)**					
Accuracy Neutral	**.77(.001)**	**.77(.001)**				
Bias Angry	**.30(.013)**	.13(.270)	.03(.764)			
Bias Happy	-.08(.503)	.16(.174)	.07(.530)	-.16(.193)		
Bias Neutral	.01 (.912)	**-.26(.031)**	.14(.227)	**-.34(.004)**	**-.35(.003)**	-

7.4.2 Event Related Potentials (ERPs)

7.4.2.1 Preliminary analyses

7.4.2.1.1. The effect of child age and gender on amplitude of ERPs

Pearson's correlations examined associations between child age and mean amplitude at the four scalp regions (N=61). Age was not associated with amplitude at any scalp region used in analyses for the targeted ERP components for each condition (in the range of Pearson's r from .02 to -.23, $p>.05$). The only exception was amplitudes to neutral voices which were positively associated with child age at occipital and parietal regions for N1 ($r=.27$, $p=.037$) and also for P3 ($r=.26$, $p=.044$) and occipital N4 ($r=.26$, $p=.044$). Thus, analyses were repeated for these regions and components controlling for child age.

Independent-samples t-tests examined differences in mean amplitude values between males and females. Results showed no significant differences between males and females for the targeted ERP components in the regions of interest ($p >.05$). The only exceptions were the Slow Wave to happy voices at the central region which presented significantly greater amplitude in girls than boys [t (58) =-2.18, $p=.033$; Girls: M=7.14 μV, SD=8.75 μV; Boys: M=2.18 μV, SD=7.41 μV] and the N1 to angry voices in the temporoparietal region which was attenuated in girls compared to boys [t (58) =-2.34, $p=.023$; Girls: M=1.72 μV, SD=3.42 μV, Boys: M=-.21 μV, SD=2.60 μV]. Therefore, subsequent analyses for the central Slow Wave and the temporoparietal N1 were repeated controlling for child gender.

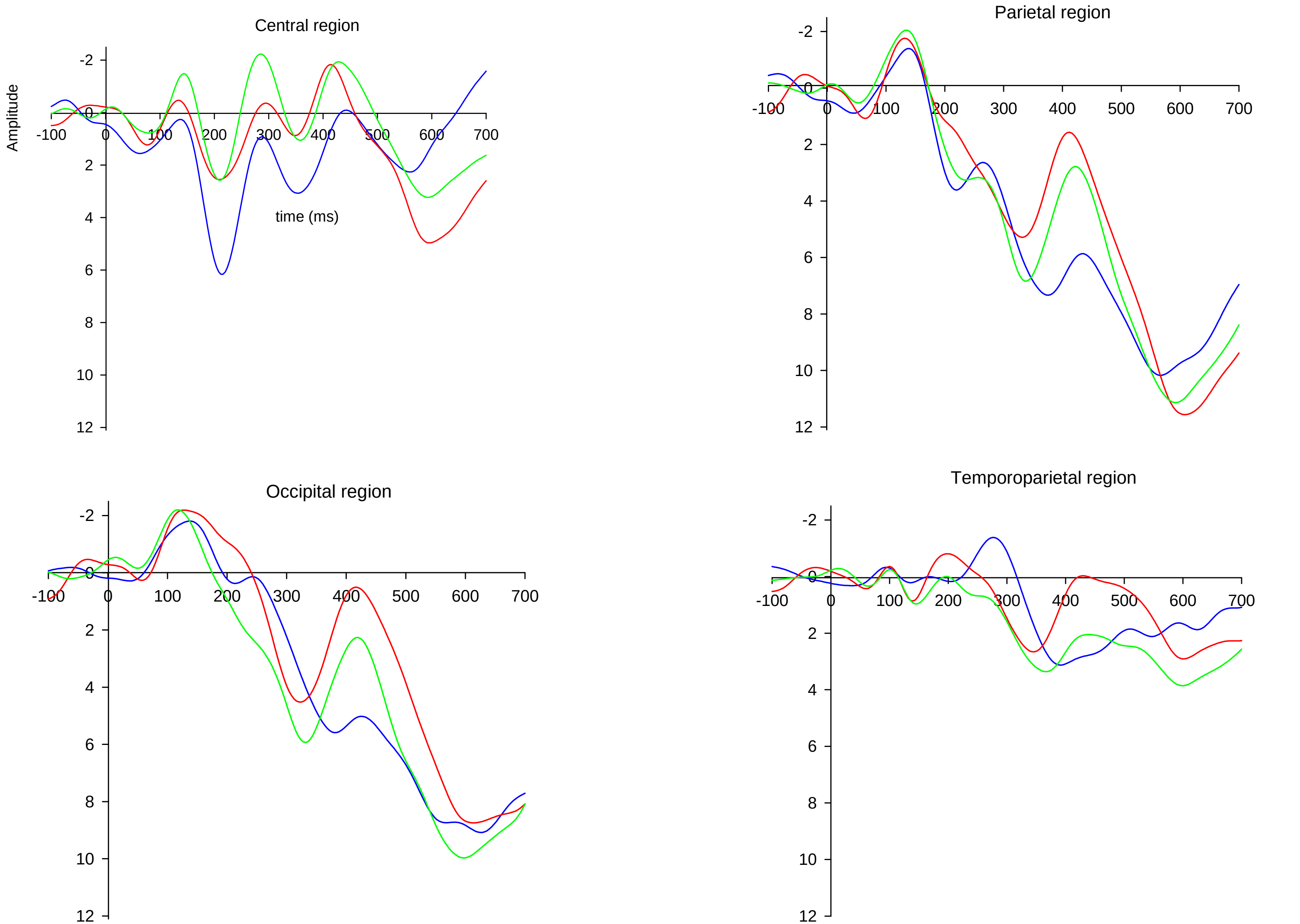


Figure 7. 3. Grand mean ERPs to angry, happy and neutral voices. Amplitude (μV) and time (ms) are marked at all regions with a pre-stimulus baseline of -100 ms. Scale is -2 to + 12μV. Angry [blue line] Happy [red line] Neutral [green line]

7.4.2.2 Main analyses

7.4.2.2.1 Emotion effects on Event Related Potentials to vocal expressions

Figure 7.3 displays the grand mean ERPs to angry, happy and neutral voices. It is important to note that the broad pattern of effects in the central region was not component-specific. Repeated measures ANOVA with emotion type (Angry, Happy, Neutral) as the within-subject factor were conducted to examine the main effect of emotion on amplitude of each ERP component at each scalp region. Because the focus of the present study was on the ERP correlates of vocal anger processing, simple planned contrasts compared the angry voice condition with neutral and happy voice condition.

Analyses revealed a number of emotion effects on the amplitude of the N1, P2, P3 and N400. Results are presented in Table 7.4. In summary, results showed larger P2 and P3 amplitude for the Angry voices when compared with Happy and Neutral voices in the central region. Significantly increased P2 amplitude to Angry voices compared with Happy Voices was also observed in the parietal region. Moreover, there was a tendency for greater P3 amplitude to Angry compared with Happy voices at the parietal region. Finally, central N1 and N400 amplitude to angry voices were attenuated when compared to happy and neutral voices. The parietal N1 to angry voices was attenuated compared to neutral voices after controlling for child age.

The N400 presented the strongest pattern of emotion effects. In particular, the N400 was attenuated to angry compared to happy and neutral voices in all scalp regions, although the angry-neutral contrast just missed significance in the occipital and temporoparietal region. After controlling for child age, the difference in occipital N400 amplitude between angry and happy was rendered non-significant while the difference between angry and neutral voices became significant. In addition, after controlling for child age, the emotion effect on the occipital N1 became significant with amplitudes to angry being attenuated compared to neutral voices. The pattern of effects did not change for the occipital P3 after controlling for child age. Finally, there were no significant effect of emotion on the Slow Wave mean amplitude in any scalp region ($p > .11$). However, the central Slow Wave showed reduced amplitude to angry compared to happy voices ($p = .045$) after controlling for child gender. Some emotion effects on the N400 and central P2 and P3 survived Bonferroni correction for multiple comparisons with an accepted alpha of .05/40=.001 adopted.

Table 7. 4. *Effects of emotion on mean amplitude (μV) of the targeted ERP components to vocal expressions at the four scalp regions (N=60).*

	N1		P2		P3		N400		Slow Wave	
Region	A vs. H	A vs. N	A vs. H	A vs. N	A vs. H	A vs. N	A vs. H	A vs. N	A vs. H	A vs. N
Central	1.47 vs.-.00	1.47 vs. -0.22	5.17 vs. 1.56	5.17 vs.1.29	3.09 vs. 0.26	3.09 vs. -0.31	1.94 vs. -0.19	1.94 vs. -0.69	2.04 vs.3.50	2.04 vs.2.64
F value	6.16	8.79	22.29	29.44	9.98	15.60	5.54	11.84	2.16	.48
Significance (p value)	**.016**	**.004**	**.000**	**.000**	**.003**	**.000**	**.022**	**.001**	.147	.493
Parietal	-0.23 vs -1.29	-0.23 vs -0.97	3.63 vs. 1.58	3.63 vs. 3.01	6.22 vs. 4.52	6.22 vs.5.94	7.71 vs.3.43	7.71 vs.4.70	10.40 vs.10.02	10.40 vs.10.15
F value	1.97	1.15	6.44	.70	3.24	.08	18.36	9.70	.13	.06
Significance	.166	.288	**.014**	.403	.077	.771	**.000**	**.003**	.720	.810
Occipital	-1.16 vs.-2.18	-1.16 vs.-1.15	0.83 vs. -0.48	0.83 vs. 2.03	4.07 vs.3.58	4.07 vs.5.32	6.25 vs.1.80	6.25 vs.4.13	9.68 vs. 7.84	9.68 vs. 9.32
F value	1.69	.00	2.74	3.00	.28	2.30	19.83	3.88	.12	.76
Significance	.198	.996	.103	.088	.598	.134	**.000**	**.054**	.116	.757
Temporoparietal	0.30 vs.-.010	0.30 vs.52	0.45 vs. -0.67	0.45 vs. 0.53	1.24 vs.1.74	1.24 vs.2.44	3.86 vs. 0.51	3.86 vs.2.50	3.09 vs.2.09	3.09 vs.3.35
F value	.63	.25	3.50	.02	.45	3.81	21.60	3.75	1.26	.08
Significance	.430	.622	.066	.877	.505	.056	**.000**	**.058**	.267	.781

Note: A: Angry, H: Happy, N: Neutral. After controlling for child gender: Central SW: A<H (p=.045). A-N (p=.622), Temporoparietal N1: A-H (p=.361), A-N (p=.221). After controlling for child age: Occipital N1: A-H (p=.120), A <N (p=.025), Occipital P3 A-H (p=.175), A-N (p=.307), Occipital N4: A-H (p=.607), A <N (p=0.015). Parietal N1: A-H (p=.204), A-N (p=.023).

7.4.2.2.2 Laterality effects on Event Related Potentials to vocal expressions

Analyses explored possible laterality effects on ERPs to voices. The right and left hemisphere were compared after combining sites per region belonging to each hemisphere for each ERP component. The following groupings were created: Right Central (sites 4 and 10), Right Parietal (sites 12, 24), Right Occipital (sites 37, 38), Right Temporoparietal (sites 22, 47) –see Figure 7.2. For the left hemisphere the following groupings were created: Left Central (sites 16, 6), Left Parietal (sites 14, 26), Left Occipital (sites 39, 40) and Left Temporoparietal (sites 28, 53). The above groupings of sites were entered in a repeated measures 2 (laterality: Right, Left) x 3 (emotion type: Angry, Happy, Neutral) design ANOVA for each ERP separately with emotion type and laterality as within-subject factors. Because the focus was on anger processing, simple planned contrasts compared the angry voice condition with neutral and happy voice condition.

Child age was not associated with right and left hemisphere ERPs (Pearson's r from .07 to .97, $p<.001$). Gender differences were examined with independent samples t-tests. Results showed few significant differences between males and females. Girls presented higher amplitudes of right [$t(58)=-2.18$, $p=.033$, Girls: 8.66 μV, Boys: 3.55 μV] and left [$t(58)=-2.22$, $p=.030$, Girls: 7.65 μV, Boys: 2.56 μV] central Slow Wave to happy voices compared to boys. Also, girls presented lower amplitudes of left temporoparietal N1 to angry voices compared to boys [$t(58)=-2.50$, $p=.015$, Girls: 1.72 μV, Boys: -.36 μV]. Subsequent, analyses were repeated covarying for gender for these ERPs.

ANOVA results showed significant laterality effects on some ERPs ($p<.001$). Central N1 amplitudes were more negative in the right than left hemisphere. The central Slow Wave was enhanced at right compared to left sites. Also, the central P2 and occipital P3 were enhanced in the left than right hemisphere. The temporoparietal P3 was enhanced at right compared to left sites. There were significant emotion x laterality interaction effects on central P2, parietal N1, P2, P3 and occipital P2. Generally, amplitudes were smaller for angry but not neutral (or happy) voices in the right compared to the left hemisphere. However, these effects did not survive Bonferroni correction with an accepted alpha of .05/38=.001 adopted. Also, there was no emotion x laterality interaction effect on N400 amplitudes in any region. After controlling for child age and gender for those components affected by child age and gender, the above effects on the whole did not change. Results are presented in Table 7.5.

Table 7. 5. *Summary of effects of 3(emotion) x 2 (laterality) ANOVA on ERPs amplitude.*

Component	Effect	Contrast	Details	F-value	Significance
Central					
N100	Emotion	H vs. A	-0.29 vs. 0.97	4.62	.036
		N vs.A	-0.54 vs. 0.97	7.00	.010
	Lateral	R vs. L	-0.55 vs. 0.64	40.81	.000
P200	Emotion	H vs. A	1.14 vs. 4.40	19.27	.000
		N vs. A	0.83 vs. 4.40	25.93	.000
	Lateral	R vs. L	1.50 vs. 2.74	33.02	.000
	Emo x Lat	N vs. A by R vs. L	N: 0.40 vs. 1.25 A: 3.52 vs. 5.28	4.72	.034
P300	Emotion	H vs. A	0.69 vs. 3.10	7.45	.008
		N vs. A	0.24 vs. 3.10	10.96	.002
N400	Emotion	H vs. A	0.07 vs. 2.64	8.50	.005
		N vs. A	-0.16 vs. 2.64	13.23	.001
Slow Wave	Lateral	R vs. L	4.53 vs. 3.19	15.05	.000
Parietal					
N100	Emo x Lat	H vs. A by R vs. L	H:-1.17 vs. -1.59 A: -0.43 vs. -0.26	4.06	.048
P200	Emotion	H vs. A	1.34 < 3.30	6.15	.016
	Emo x Lat	N vs. A by R vs. L	N:2.86 vs. 2.65 A: 2.91 vs. 3.69	6.49	.013
P300	Emo x Lat	N vs. A by R vs. L	N: 4.32 vs. 4.33 A: 5.55 vs. 6.23	4.19	.045
N400	Emotion	H vs. A	3.13 vs. 7.39	18.46	.000
		N vs. A	4.48 vs. 7.39	8.96	.004
Slow Wave	-	-	-	-	*ns.*
Occipital					
N100	Lateral	R vs. L	-1.32 vs. -1.66	3.48	.067
P200	Emo x Lat	H vs. A R vs. L	H: -0.28 vs. -0.68 A: 0.62 vs. 1.04	3.60	.063
P300	Lateral	R vs. L	4.01 vs. 4.62	4.08	.048
N400	Emotion	H vs. A	1.80 vs. 6.25	19.83	.000
		N vs. A	4.13 vs. 6.25	3.88	.054
	Lateral	R vs. L	3.50 vs. 4.62	9.93	.003
Slow Wave	-	-	-	-	*ns.*
TemporoParietal					
N100	-	-	-	-	*ns.*
P200	Emotion	H vs. A	-0.66 vs. 0.45	3.50	.066
P300	Emotion	N vs. A	2.44 vs. 1.24	3.81	.056
	Lateral	R vs. L	2.27 vs. 1.34	4.97	.030
N400	Emotion	H vs. A	2.50 vs. 3.85	21.60	.000
Slow Wave	-	-	-	-	*ns.*

Abbreviations: A: Angry, H: Happy, N: Neutral, Lat: Lateral, Emo: Emotion, R: Right, L: Left. After controlling for child gender: Laterality effects on Central Slow wave did not hold (p=.34), also, sig laterality effect (p=.004, R>L, .47>.01) and emo x lat interaction effect (p=.017, H vs. A by R vs. L, H: .35 vs. -.57, A: .41 vs. .19) emerged on Temporoparietal N1. These effects did not survive Bonferroni correction.

7.4.2.2.3 Summary of Emotion Effects: Markers of vocal anger processing

The above analyses revealed some candidate components indexing vocal anger processing. These components consisted of the N1, P2 and P3 in central regions and the N400 across scalp regions. The pattern of effects in the central region was not component-specific. In contrast, the N400 was the strongest index of vocal anger processing. Emotion x laterality interaction effects on ERP amplitudes were few. The above ERP components may provide reliable markers of emotion processing in children as they show a stable and consistent profile of emotion effects, especially for anger compared with happy and neutral voice processing. The above ERPs will be examined in subsequent analyses to investigate links with psychopathology.[5]

7.4.3 Psychopathology

7.4.3.1 Child Psychopathology

A second aim of the current study was to explore associations between ERP markers of vocal anger processing and behaviour problems in children. Details regarding child symptoms in the whole sample are provided in Section 6.2

7.4.3.1.1 Child Psychopathology and Performance

Pearson's correlations examined associations between child behaviour and discrimination accuracy and response bias. Results showed no significant associations between child symptoms and performance. This was not surprising given that performance was at ceiling levels and that the study was designed to pick up individual differences at an electrophysiological rather than a performance level. Results are presented in Appendix D.

[5] Because of the high levels of performance required for the ERP task, it was not expected that performance would be correlated with ERPs. Associations between performance and ERPs are presented in Appendix D.

7.4.3.1.2 Child Psychopathology and Event Related Potentials

Pearson's correlations examined the relationship between child psychopathology and ERP markers of vocal anger processing. These associations were studied in two ways. First, each of the ERP components separately (N1, P2, P3 and N400) to angry, happy and neutral voices were correlated with child symptoms of psychopathology, including hyperactivity, conduct problems, emotion dysregulation, depression and anxiety. Second, because associations with happy and neutral voices were in the same (negative) direction as angry and in order to isolate effects specific to anger processing a difference score was created per component by subtracting the mean amplitude to neutral voices from the mean amplitude to angry voices. Pearson's correlations examined the relationship between child symptoms and the A-N (angry minus neutral) amplitude difference score for each component indexing vocal anger processing (N1, P2, P3 and N400).

Results from the first set of analyses showed that emotion dysregulation was negatively associated with N400 to angry voices across regions. Conduct problems were negatively associated with N400 amplitude to vocal anger across regions. No other significant associations emerged (see Appendix D). Results from the second set of analyses showed that emotion dysregulation was negatively associated with occipital and temporoparietal N400 A-N (angry minus neutral) amplitude difference score. Also, a negative association between conduct problems and temporoparietal N400 was marginally significant. When a Bonferroni correction was applied with an alpha level of .05/35=.002 adopted, these associations did not remain significant. Results are presented in Table 7.6.

Table 7. 6 *Full Pearson's correlations (p value) between child symptoms and Angry-Neutral difference amplitude score of the ERPs*

	Child Psychopathology				
ERP	Hyperactivity	Conduct Problems	Emotion Dysregulation	Anxiety	Depression
Central N1	-.08(.521)	-.12(.372)	-.08(.519)	-.05(.709)	-.02(.852)
Central P2	-.17(.172)	-.22(.087)	-.16(.225)	-.21(.113)	-.13(.336)
Central P3	-.12(.329)	-.16(.223)	-.13(.320)	-.08(.521)	-.09(.522)
Central N400	.02(.846)	-.15(.241)	-.23(.079)	.10(.431)	.13(.320)
Occipital N400	-.11(.378)	-.21(.097)	**-.29(.027)**	-.10(.419)	-.17(.193)
Parietal N400	.00(.945)	-.14(.272)	-.19(.143)	-.02(.857)	-.03(.842)
TempPar N400	-.13(.290)	**-.25(.051)**	**-.35(.006)**	.11(.400)	.05(.704)

7.4.3.2 Parent Characteristics

A final aim of the study was to explore associations between ERP markers of vocal anger processing and parent characteristics. Details regarding parent characteristics in the whole sample are provided in Section 6.2.

7.4.3.2.1 Parent Characteristics and Children's Performance

Analyses examined the relationship between parent characteristics and children's discrimination accuracy and response bias to vocal expressions. As performance-based measures were not the focus of this study, results are summarised in Appendix D.

7.4.3.2.2 Parent Characteristics and Children's ERPs

As above, a first set of Pearson's correlation analyses examined the relationship between parent characteristics and those ERPs that showed emotion effects on amplitude. Results showed that symptoms of parent hyperactivity were positively associated with children's central P2 ($r=.27$, $p=.039$) and P3 ($r=.30$, $p=.018$) to angry voices. In addition, symptoms of parent depression were negatively associated with children's N400 amplitude to angry voices in central, parietal, occipital, and temporoparietal regions ($p<.040$). There was also a negative relationship between symptoms of parent depression and children's parietal temporoparietal N400 amplitude to neutral voices ($p<.040$). Results did not survive Bonferroni correction for multiple comparisons. No associations emerged between parenting sense of competence and children's emotion processing ($p >.05$). Results are presented in Appendix D.

A second set of analyses in line with the study's focus on vocal anger processing examined the relationship between parent characteristics and children's ERPs using the A-N (angry minus neutral) amplitude difference score. Pearson's correlations revealed no significant associations between parent characteristics and the A-N (angry minus neutral) amplitude difference score for any ERPs, suggesting that the associations between children's ERPs and parent characteristics found above may not be specific to vocal anger. Because parent and child symptoms were positively associated, the above analyses were repeated controlling for child symptoms. No associations emerged between parenting sense of competence and children's emotion processing ($p >.05$). Results did not change even after controlling for child symptoms ($p >.05$). Results are presented in Table 7.8.

Table 7. 8. *Full Pearson's correlations (p value) between parental psychopathology and A-N (angry minus neutral) amplitude difference score (N=60)*

	Parental Psychopathology			
ERP	Inattentive	Hyperactive	ADHD combined type	Depression
Central N1	.08(.526)	-.06(.635)	.01(.898)	.20(.108)
Central P2	.00(.961)	.12(.363)	.07(.616)	.03(.795)
Central P3	.15(.252)	.08(.535)	.13(.317)	.03(.804)
Central N400	.07(.576)	.01(.896)	.05(.690)	-.09(.501)
Occipital N400	-.07(.615)	-.14(.278)	-.11(.389)	-.07(.568)
Parietal N400	.06(.634)	-.05(.688)	.01(.942)	-.02(.883)
TemPar N400	-.04(.756)	.02(.840)	-.01(.937)	-.08(.530)

The primary aim of the present study was to investigate the neural correlates of vocal anger processing in 6- to 11-year-old children and explore links between neural markers of vocal anger processing and child psychopathology.

In this study, children achieved an overall recognition accuracy of 86.62% suggesting that the vocal emotion identification task worked well for the purposes of the ERP study. Given the young age of the children and similar developmental ERP research (Vlamings et al., 2010), the task was designed in such a way as to maximise the number of correct trials per condition. Children's hearing threshold was not associated with accuracy suggesting that performance differences were not attributable to auditory processing abilities. Children presented a higher bias to neutral voices, in other words, a higher tendency to classify a vocal expression as neutral.

First, the ERP components observed in the study were compatible with those reported in the literature of vocal emotion processing in adults (Schirmer & Kotz, 2006) and voice processing in adults (Belin & Zatorre, 2000) and children (Bruneau et al., 1997; Rogier et al., 2010). The present study showed that children's ERPs were sensitive to vocal anger. Importantly, the study showed a significant effect of emotion on the N400 across scalp regions. The finding that ERPs to voice processing are modulated by anger prosody in 6- to 11-year-old children is a novel finding given the paucity of developmental research investigating the time course of the processing of anger prosody.

In the current study the N400 was attenuated for angry compared to happy and neutral voices across regions. The N400 is thought to reflect processing of semantic integration in adults (Kerkhofs, Dijkstra, Chwilla, & de Bruijn, 2006) and semantic context match/mismatch in toddlers (Nelson & McCleery, 2008). Previous research suggests that the N400 may be an index of emotional prosody perception (Bostanov & Kotchoubey, 2004; Schirmer et al., 2002; Toivonen & Rämä, 2009). For instance, positive words elicited smaller N400 when preceded by a prime with congruous as compared to incongruous emotional prosody (Schirmer et al., 2005). Findings of the present study regarding the N400 are rather compatible with adult studies showing reduced N400 amplitudes to negative compared to neutral emotional stimuli (Kanske & Kotz, 2007). This finding has been replicated in a number of recent studies in healthy adults (Gootjes, Coppens, Zwaan, Franken, & Van Strien, 2011; Stewart et al., 2010). Based on models of language processing linking smaller N400 amplitudes to facilitated processing of words that are congruous with a semantic context (review by Kutas & Federmeier, 2000; Kutas & Hillyard, 1980), reduced N400 amplitudes to negative emotional words has been suggested to reflect facilitated processing of negative compared to neutral words in healthy adult individuals (Kanske & Kotz, 2007; Stewart et al., 2010). This interpretation of facilitated processing of anger, which has consistently been adopted previously in the emotion processing adult literature, seems to be in agreement with findings of the present study.

The central N1 was attenuated to angry and happy compared to neutral voices. Previous research found no effects of angry and happy prosody on the N1 in 9- to 12-year-olds (Korpilahti et al., 2007) and adults (Bostanov & Kotchoubey, 2004; Erhan et al., 1998; Spreckelmeyer et al., 2009); the small sample sizes used, however, might explain a failure to identify emotion effects. Findings from this study agree with Yagura and colleagues (2004) showing larger N1m for positive (happy) compared to negative (sad) prosody. Notably, the N1 (alongside the N400) showed enhanced amplitudes for neutral compared to emotional stimuli. It is interesting to note that, at a behavioural level, children also showed a higher tendency to classify voices as neutral.

The central P2 was larger for angry compared to happy and neutral voices. In the adult literature, there is little agreement on vocal emotion modulation of the P2 (Paulmann & Kotz, 2008a; Schirmer et al., 2005). Results of this study are consistent with adult research showing larger P2 to negative compared to neutral and positive pictures (Carretie', Martin-Loeches, Hinojosa, & Mercado, 2001) and negative compared to neutral words in an emotional Stroop task (Thomas, Johnstone, & Gonsalvez, 2007). The central P3 was also enhanced to angry compared to happy and neutral voices in this study. In previous research, the P300 did not differentiate between positive and negative vocal stimuli in adults (Kotz & Paulmann, 2007). Results from this study are consistent with research with facial stimuli showing a larger late positive component for angry compared to happy expressions in children (Kestenbaum & Nelson, 1992; Lewis et al., 2007).

Laterality effects were few and inconsistent in this study. Central P2 and occipital P3 amplitudes were larger in the left than right hemisphere whereas temporoparietal P3 and central N1 amplitudes were larger in the right than left hemisphere. Emotion interacted with laterality but these effects were not strong and were not evident for the N400. In recent studies, happy voices elicited increased brain activation in the right hemisphere in infants (Grossmann et al., 2010) and adults (Johnstone et al., 2006) compared to angry or neutral voices. Some ERP studies have shown bilateral activation to emotional prosody (Kotz, Meyer, & Paulmann, 2006), although existing literature does not present a coherent picture (Kotz et al., 2003; Wildgruber et al., 2006).

In summary, the present study provided for the first time evidence on the influence of anger prosody on the ERP (e.g. N400) of a large sample of 6- to 11-year-old children. Findings underscore the adaptive value of vocal anger processing in typical development

(Vaish & Striano, 2004) and have important implications for children's socio-emotional adjustment (Denham, 1998). Previous studies in small samples of children have used linguistic stimuli in simple passive listening (Korpilahti et al., 2007) or complex attention tasks (Shackman et al., 2007) and have not included neutral voice as a control condition for comparison with emotional voices. Therefore, the anger modulation of the N400 in the present age group is an interesting and novel finding in an active vocal emotion recognition task.

The strengths and limitations of the method of analysis followed in the current study should be acknowledged. The present study, in accordance with previous literature in children of similar ages, followed a baseline-to-peak amplitude method by measuring the voltage difference between the voltage at a peak and a baseline level. It is recommended to measure the average activity across a particular latency range (mean amplitude), when the component under analysis does not have a definite peak (Fabiani et al., 2007). A disadvantage of this method, however, is that it may be sensitive to noise or nonlinear fluctuations in the baseline time window. An alternative method of quantifying the ERP signal would be to adopt a *peak-to-peak amplitude* method by measuring the peak relative to an adjacent peak or though. The strength of this method is that it remains free from very slow EEG activity in the baseline (Picton et al., 2000) and can be an index of temporally localised activity in cases in which the peaks of interest are superimposed on a slower wave or a sloping baseline shift. An extensive discussion of the advantages and disadvantages of different methods of ERP analysis is provided in section 5.1.4.

In the present study a high frequency signal seemed to be superimposed on a low frequency oscillation (i.e delta/theta). Frequency domain analysis of the ERPs would provide some useful information regarding this issue. Oscillatory responses represent changes in the ongoing EEG activity temporally related to a defined event (delta: approx 0.5-3.5 Hz, theta: 4-7 Hz, alpha: 8-13 Hz, beta: 15-30 Hz and gamma: 30-80 Hz). Event-related oscillations are correlated with several brain functions. Functions are also related to the superposition of several oscillations (Basar, Basar-Eroglu, Karakas & Schurmann, 1999). Several methods, including the Fourier transformation and wavelet analysis, can be applied to extract oscillations of a specific frequency from ERP data (Herrmann, Grigutsch & Busch, 2005). Evoked delta and theta oscillations represent the slow potentials in ERPs such as the P3 and the N400 (Basar-Eroglu, Bagar, Demiralp, & Schiirmann, 1992). The delta response is typically related to signal detection and decision making (Basar, 1998; Basar et al., 1999).

Recent research suggests that emotion processing may be related to and affect delta frequency activity. In a recent study event-related delta oscillations were modulated by the valence of affective pictures (unpleasant pictures provoked greater delta responses than pleasant pictures). In the same study arousal effects on delta oscillations were also found (Klados et al., 2009). Frequency bands variations can also reflect the motivational significance of facial expressions (Aftanas, Varlamon, Pavlov, Makhnev, & Reva, 2002). For example, delta and theta band power have been associated with emotional (fear, happiness, sadness) compared to neutral facial expressions. In addition, amplitudes of delta and theta accounted for the amplitude of a correspondent N2 component indexing comprehension of facial emotion (Balconi & Pozzoli, 2007). In light of the above findings, it can be concluded that brain oscillations can be a powerful index of the cognitive processes related to emotion processing. Oscillatory analysis would therefore represent a fruitful avenue for further investigating the present ERP data.

Second, following the identification of ERP markers of vocal anger processing, the study aimed to explore the relationship between neural markers of anger processing and child behaviour problems. Overall, the study found few associations between child psychopathological symptoms and ERPs. The study showed that emotion dysregulation was negatively associated with the A-N (angry minus neutral) amplitude difference score for the N400 in the temporoparietal and occipital region. In addition, there was a marginal inverse relationship between conduct problems and the A-N (angry minus neutral) amplitude difference score for the temporoparietal N400. In other words, the difference in N400 amplitudes between angry and neutral voice processing tended to become smaller as the level of child symptoms increased. One possible interpretation for this could be that angry and neutral vocal expressions may be processed in a similar way in children with conduct problems.

The present study provided initial support for the relationship between conduct problems and the neural correlates of vocal anger processing, although the effects were marginal. A smaller difference in the N400 amplitude between angry and neutral may suggest that children with conduct problems may not be able to clearly differentiate between cues signalling social punishment (i.e. anger) from neutral signals. For example, previous research has found reduced amygdala activation to angry compared to neutral facial expressions in adolescents with conduct disorder, an effect which was driven by increased amygdala activation to neutral facial expressions (Passamonti et al., 2010). Other studies support the idea that hostile attribution biases may originate from a heightened tendency to perceive others as ‘angry’ early in life (Fine et al., 2004; Lansford et al., 2006; Pettit et al., 2010) and a vulnerability to perceive anger even in the absence of concordant cues (de Castro et al., 2005), which might explain involvement in aggressive interactions with others. Poor understanding of anger may contribute to misinterpretations of neutral expressions as signs of anger and lead to emotion dysregulation and conflict (Schultz et al., 2000; Schultz et al., 2004).

Anger perception processes may reflect broader regulatory processes subsumed under the general term ‘emotion regulation’ which refers to attempts to control, modify, and manage the experience and expression of emotion (Cole, Dennis, Smith-Simon & Cohen, 2009; Cole, Michel, & Teti, 1994; Gross, 1998). Emotion dysregulation has been reported in children with a number of behaviour problems (Eisenberg et al., 2001), including both externalising and internalising problems (Hinshaw, 2003; Rubin, Chen, McDougall, Bowker, & McKinnon, 1995) and may moderate the relationship between children’s negative emotionality (i.e. anger) and behaviour problems (Eisenberg et al., 1996; Schultz et al., 2004). Vocal anger perception difficulties may be a risk factor for involvement in aggressive interactions in conjunction with broader emotion dysregulation. Recent research has shown that changes in the cortical mechanisms for regulating negative emotion were associated with clinical improvement in children with behaviour problems (Lewis et al., 2008). It is also interesting to note that the above marginal associations emerged only with conduct problems and not hyperactivity. It should be noted, however, that the above results did not survice Bonferroni correction for multiple comparisons.

Third, the present study showed few associations between child ERPs and parent characteristics. In particular, symptoms of parent hyperactivity was positively associated with P2 and P3 amplitudes to angry but not happy or neutral vocal expressions, although this association did not hold for the A-N (angry minus neutral) amplitude difference scores. Amplified attention to threat-related signals (anger) has previously been shown in children experiencing atypical parenting environments, such as physical abuse or maltreatment (Cicchetti & Curtis, 2005; Pollak, Messner, Kistler, & Cohn, 2009; Shackman et al., 2007). Future studies should aim to explore further links between parental externalising psychopathology and children’s atypical neural responses to vocal anger.

A main limitation of the present study was the low level of child symptoms in the sample, which in combination with the ceiling levels of performance, might not have allowed clear associations between child psychopathology and vocal anger ERPs to emerge. Given the sampling strategy, this study did not have sufficient power to test for associations between child symptoms and neural markers of vocal anger processing. Future studies should replicate the present findings in a clinical sample of children with conduct problems and emotion dysregulation.

Finally, it is essential to further explore facial as well as vocal anger perception in this group of children to establish whether the observed effects were modality-specific or spanned across modalities. This formed the primary aim of the following study.

Chapter 8. Study 5. The Electrophysiological Correlates of Facial Anger Processing in Children and Links to Behaviour Problems

8.1 Introduction

The present study investigated the neural correlates of facial anger processing in typically developing school-aged children. The primary objective was to examine whether a marker of anger processing found in Study 4 would span across modalities (face/voice).

A first aim of this study was to examine whether emotion modulates the ERPs of typically developing 6- to 11-year-old children during face processing. There is some inconsistency in the literature regarding the facial emotion modulation of early latency ERPs (e.g. P1, N170), with some studies showing emotion effects on early ERPs in healthy adults (Eimer & Holmes, 2002; Leppänen, Moulson, Vogel-Farley, & Nelson, 2007; Pourtois et al., 2004) and infants (Grossmann et al., 2007; Nelson & de Haan, 1996), whilst other studies have not found an effect of emotion on early latency ERPs in adults (Eimer et al., 2003; Herrmann et al., 2002; Pizzagalli et al., 2002) or infants (Leppänen, Kauppinen, Peltola, & Hietanen, 2007). Thus, the neural developmental pattern of early perceptual stages of processing emotional faces remains unclear.

Emotion effects on parietal-occipital P1 latency (earlier for happy compared to disgust, fearful and sad faces) have been found in younger (4- to 5-year-old and 6- to 7-year-old) but not in older (8- to 9-year-old and 10- to 11-year-olds) children in implicit emotion identification tasks (Batty & Taylor, 2006). In contrast, emotion effects on the N170 amplitude (larger for angry compared to happy and neutral faces) were found only within the oldest (i.e. 14- to 15-year-olds) group of participants (Batty & Taylor, 2006). Similarly, in younger (5- to 9-year-old) children, no emotion effects were found on the N170 (190 ms) at parietal occipital sites, in a cued reaction time flanker task with emotional faces as distractor stimuli (Dennis et al., 2009). Similar studies with younger (4- to 6-year-old) children have not found effects of emotion on the amplitude or latency of the occipital N170 (266 ms) when children viewed angry and happy facial expressions in an emotional Go-NoGo task (Todd et al., 2008). Recent studies have shown effects of facial emotion on the P1 amplitude (larger for fearful compared to neutral) and N170 amplitude (larger for neutral compared to fearful) in 3- to 8-year-olds, only under the condition of facial expressions being presented with high spatial frequency (finer visual information) compared to a low spatial frequency (global face configuration) (Vlamings et al., 2010).

P1 has been suggested to reflect top-down attentional influences on face processing and to be an index of global and rapid processing of faces rather than a 'face-specific' component (de Haan et al., 2003). Therefore, emotion effects on the P1 found in the above studies may be due to a superficial global visual processing of faces, evident in younger children (Batty & Taylor, 2006). In contrast, a finer discrimination of facial features including subtle emotional changes in the face, as indexed by the 'face-specific' N170 seems to emerge later in development, at about 14 years of age (Batty & Taylor, 2006). It has been suggested that the finer-grained analysis of emotion (N170) follows a prolonged developmental course until adolescence, as reflected by a decrease in N170 latency with increasing age, and replaces the global processing of emotions seen in childhood, as reflected by a dramatic decrease in P1 amplitude with age (from 4-9 years to 10-15 years) (review by Taylor et al., 2004). This is compatible with behavioural studies, showing that 11-year-olds made significantly more errors in facial emotion recognition tasks compared to children aged 12 years or older (Tonks et al., 2007).

Evidence on emotion effects on late latency ERPs is not uniform across studies. There is some consistency in the literature for larger amplitudes of late positive components in response to negative compared to positive facial emotional expressions in children (Dawson et al., 2004; Kestenbaum & Nelson, 1992; Todd et al., 2008). Similar effects have been found on the late negative components at about 390-450 ms in school-aged children (Batty & Taylor, 2006; Nelson & Nugent, 1990). However, other research did not find significant emotion effects on the late positive components (Shackman et al., 2007) or negative components in typical school-aged children (Battaglia et al., 2005) and 5-year-old children (de Haan et al., 1998).

From a methodological viewpoint, it should be noted that all studies reviewed above used implicit emotion processing tasks (Batty & Taylor, 2006; Shackman et al., 2007) or complex cognitive control tasks (Dennis et al., 2009; Todd et al., 2008) and therefore, only implicit processing of facial emotion was assessed in those studies. No ERP studies have examined whether the above findings would generalise to an explicit emotion identification task in typically developing school-aged children.

Finally, few laterality effects on children's ERPs to emotional faces have been reported in the literature. Laterality effects on facial emotion processing, in favour of the right hemisphere, have previously been reported in adults (Adolphs, 2002; Utama et al., 2009) but not in 4- to 6-year-old children in relation to the N170 (Todd et al., 2008). Other studies have shown that by 5 years of age, the N170 peaked earlier at left compared to right hemisphere sites. Also, larger N170 amplitudes were observed at the right but not left hemisphere in response to angry but not happy faces (de Haan et al., 1998). In summary, laterality effects on facial emotion processing in children are few and inconsistent.

A second aim of the present study was to explore potential associations between children's ERPs during facial emotion processing and externalising and internalising behaviour problems. The present study adopted a special focus on anger because this is the emotion that has been highlighted by previous behavioural (Kats-Gold et al., 2007; Pelc et al., 2006) and electrophysiological (Monk et al., 2008; Williams et al., 2008) work in children with externalising and internalising symptoms.

One study has examined ERP data of adolescents with ADHD and matched controls during a facial emotion recognition task (Williams et al., 2008). The study showed that the left occipital N170 (120-220 ms) was enhanced in ADHD adolescents for angry and fearful faces compared to healthy controls, possibly suggesting an over processing of emotional information related to anger and fear (Williams et al., 2008). Second, the study showed reduced left occipital P120 (120 ms) to angry faces, suggesting that the early perceptual analysis of threat-related (i.e. angry) signals may be impaired in this patient group. Third, a reduction and delay in the temporal P300 (300-400 ms) for anger and fear was observed in the ADHD participants only, possibly reflecting difficulties with contextual processing of anger (Williams et al., 2008).

A second ERP study showed that adults with ADHD presented reduced EPN (early posterior negativity; 170-300 ms) in response to happy than neutral pictorial stimuli compared to healthy adults (Herrmann et al., 2009). This suggests a lower reactivity to positive stimuli in ADHD and is compatible with motivational-reward system dysfunctions in ADHD (Sonuga-Barke et al., 1992). Neuroimaging work has shown enhanced activation in response to angry facial expressions during an implicit (i.e. gender decision) task in regions of the frontal and posterior cingulate cortex in adolescents with ADHD (Marsh et al., 2008).

As the mean age in the above ERP and imaging studies was 14 years, it is not clear whether deficits in facial anger processing would generalise to younger children with ADHD symptoms. Studies with younger children would help clarify whether the psychophysiology of anger related brain alterations change with development. In addition, it is not clear from the above ERP studies whether conduct problems would make a distinctive contribution to facial anger processing. Differences in emotion processes have been associated with conduct problems (Sharp et al., 2008) and oppositionality (Stringaris et al., 2010) in children. ERP methods, because of their high temporal resolution, are a powerful tool in clarifying the neural mechanisms underlying facial anger processing in this group of children.

ERP studies using facial stimuli in young children with conduct problems are limited. Adolescents with CD presented impaired recognition of anger from facial expressions (Fairchild et al., 2009). Children with conduct problems were found to present reduced recognition of fearful and sad facial expressions in behavioural studies (Blair et al., 2001; Blair et al., 2005; Stevens et al., 2001). These findings have been interpreted as lower empathy when viewing others experiencing emotional distress (Blair, 2001; Blair et al., 1999; de Wied et al., 2010). Deficient affective processing has been a core deficit in adult psychopathic individuals who showed less behavioural and electrocortical differentiation between emotional and neutral words (Williamson et al., 1991).

Existing deficits in adolescents with conduct disorder have mainly been interpreted in relation to dysfunction in the amygdala (review by Marsh & Blair, 2008) and ventromedial prefrontal cortex (Blair, 2008). Recent research has shown amygdala hypo activity to fearful faces in 10- to 12-year-olds (Jones et al., 2009) and adolescents (Marsh et al., 2008) with conduct problems. Adolescents with conduct disorder showed reduced amygdala activation than healthy controls to angry compared to neutral faces, although this effect was driven by a differential group response to neutral compared to angry faces (Passamonti et al., 2010). Beyond this imaging evidence, however, no studies have explored the time course (ERPs) of anger processing in children with conduct problems.

A last question is whether the aforementioned deficits would be independent of internalising problems in children. The importance of facial anger has been highlighted in the pathogenesis of internalising symptoms in children and adolescents (Lenti et al., 2000). As Chapter 5 argued, adult anxiety has been linked to increased P1 amplitudes towards targets in the same location as angry faces in dot-probe tasks (Santesso et al., 2008) and larger occipito-temporal N170 amplitudes to angry faces (Rossignol & Campanella, 2008). Trait anxiety in children was associated with increased right prefrontal cortex activation to angry faces reflecting attention bias for angry faces (Telzer et al., 2008). Similarly, individuals with depression are characterised by increased vigilance and selective attention to negative (i.e. sad) stimuli (review by Bourke et al., 2010). Preferential increases in neural responses to negative compared to positive faces have also been shown in adults with major depression (Surguladze et al., 2005). Behavioural research has shown low recognition for neutral facial expressions in children with emotional problems (Leist & Dadds, 2009) and decreased accuracy to recognise facial expressions in general with increased anxiety levels in children (Richards et al., 2007).

8.2 Aims

The aims of the present study were as follows:

1. To examine the neural correlates of facial anger processing in typically developing 6- to 11-year-old children from the community.

2. To explore associations between the neural markers of facial anger processing and child externalising and internalising symptoms.

3. To explore the role of parental psychopathology in children's neural processing of facial anger.

8.3 Preliminary ERP Data Treatment

Visual inspection of ERP data revealed some between-subject variation in ERP component morphology. A peak latency and mean amplitude method for selected ERP components was judged most suitable for the aims of the present study and was consistent with previous ERP studies in facial emotion processing in children (Batty & Taylor, 2006).

Baseline-to-peak amplitudes and peak latencies were calculated for the following components: P100 (110-200 ms) and N170 (170-320 ms). A mean amplitude method was followed for the P300 (340-430 ms), the early Slow Wave (ESW; 430-520 ms) and the late Slow Wave (LSW; 520-610 ms). The above time windows were selected because they best captured each ERP component identified by visual inspection of the ERP averages across regions. Figure 8.1 illustrates the targeted ERP components in this study. Selection of the above components and time windows was literature informed. The above components have previously been shown to be differentially sensitive to both face processing (Halit et al., 2003; Itier, Latinus, & Taylor, 2006) and facial emotion processing (Batty& Taylor, 2006).

Analyses focused on 19 electrode sites (see Figure 8.2) with equal distribution across central, parietal, occipital, and temporal scalp areas. Mean amplitude and latency was initially calculated for each individual site and subsequently the mean amplitude and latency for the ERP components was calculated as a combined score for a number of defined groups of electrode sites (henceforth termed ‘ scalp regions’), in order to increase the reliability of measurement (Dien & Santuzzi, 2005). Selection of sites for each region was based on the strong correlation between the grand average ERP waveforms for each electrode within that region. The grand ERP averages for individual sites are available in Appendix E. The regions of interest were identical as in the previous study. Correlations between ERP waveforms within each of the above regions were statistically much stronger (Pearson’s $r=.50$ to $.95$, $p<.001$) compared to correlations between amplitudes of sites belonging to different regions (Pearson’s $r=.14$ to $.75$, $p<.001$).

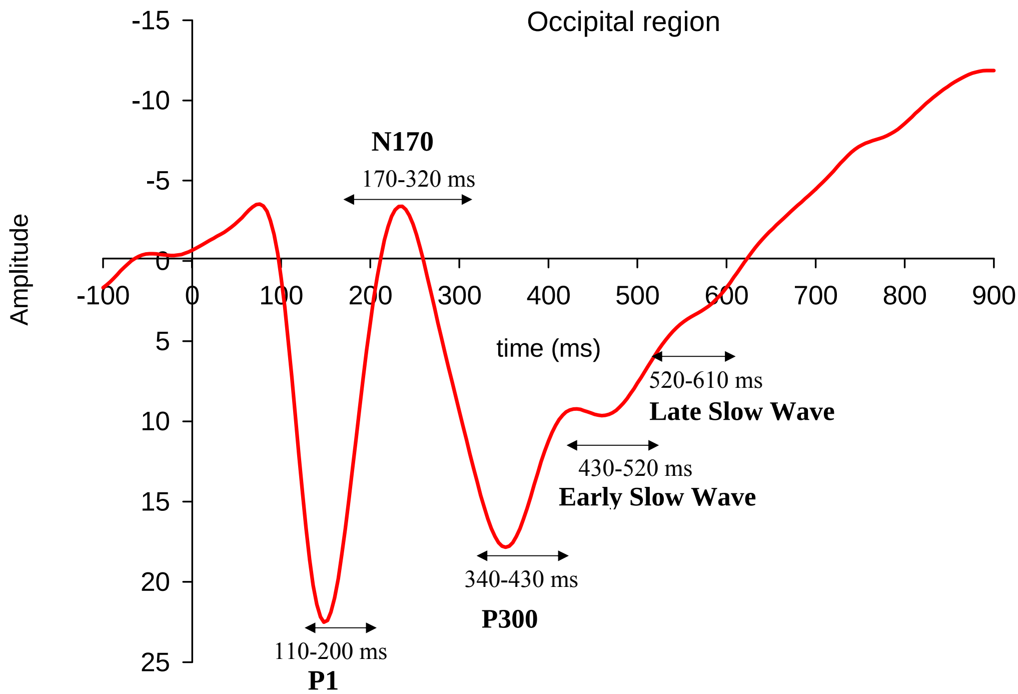
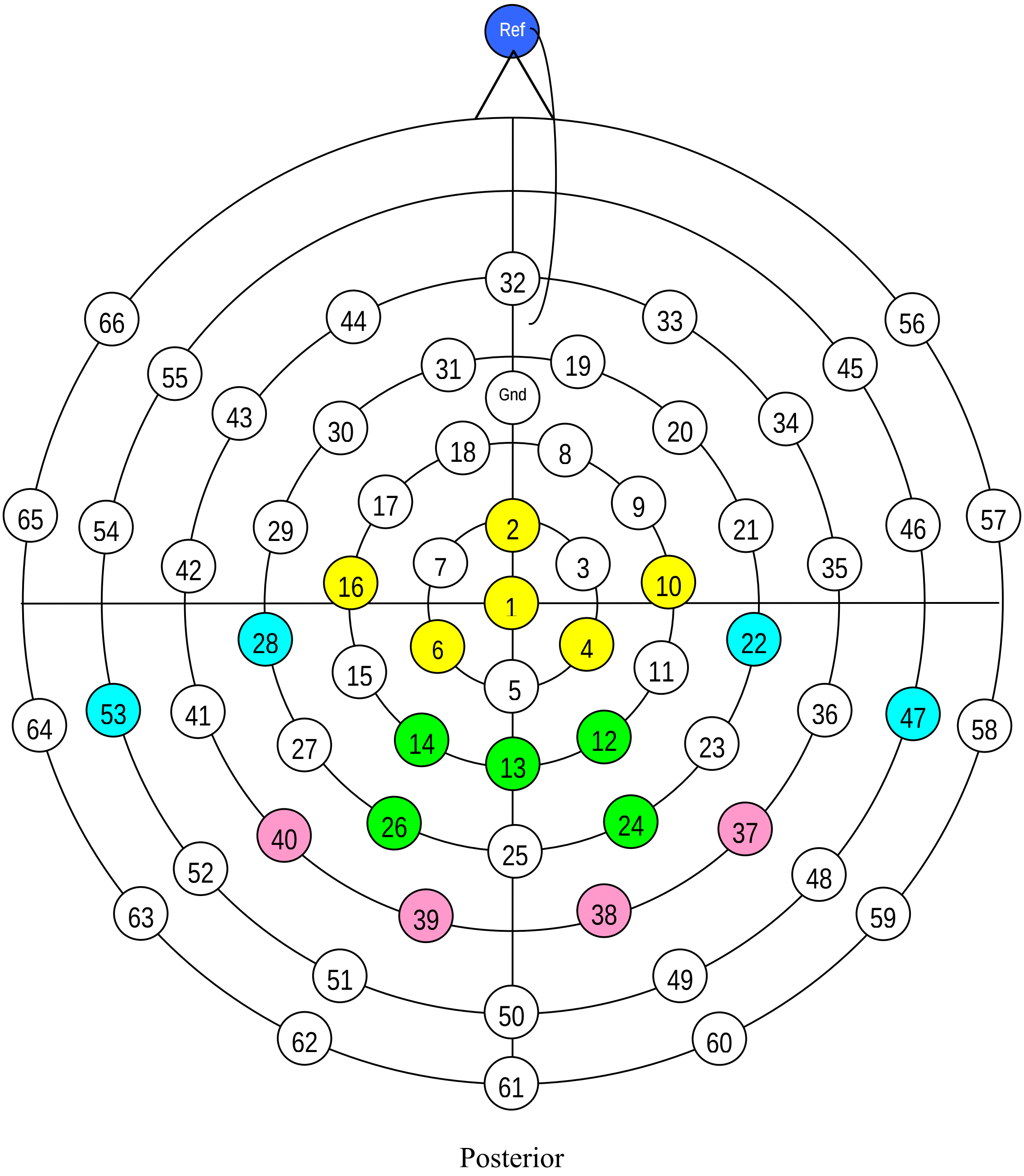


Figure 8. 1. Grand average ERP across emotions (angry, happy and neutral) in the occipital region illustrating the targeted ERP components to faces. Scale is -15 to + 25 µV.



Central region sites
Parietal region sites
Occipital region sites
Temporoparietal region sites

Figure 8. 2. Montage with 19 sites used in EEG recording and sites per region in Study 5.

8.4 Results

8.4.1 Performance

Following data processing, conducted as specified in Section 3.4, initial analyses aimed to explore the general performance levels of discrimination accuracy and response bias.

8.4.1.1 Initial data treatment

Kolmogorov-Smirnov tests indicated that values of discrimination accuracy were significantly different from normality ($p < .001$). Values for response bias did not differ significantly from normality ($p > .05$). Because accuracy values were not normally distributed due to ceiling effects, and could not be transformed, non-parametric tests were used.

8.4.1.2 Emotion processing measures and child age and gender

Non-parametric Spearman's correlations showed that child age was not significantly associated with accuracy or bias for angry, happy or neutral faces ($p > .05$). Mann-Whitney U tests showed no significant difference between boys and girls in accuracy for angry (U=575.00, z=-.29, p=.771, r=-.03), happy (U=521.00, z=-.91, p=.358, r=-.10) or neutral (U=.780, z=-.28, p=.780, r=-.03) faces. Similarly, there were no significant differences between boys and girls in response bias to angry (U=563.00, z=-.43, p=.667, r=-.05), happy (U=574.00, z=-.30, p=.762, r=-.03) or neutral (U=582.500, z=-.20, p=.839, r=-.02). Parametric and non-parametric tests for bias produced similar results.

8.4.1.3 Discrimination accuracy and response bias overall performance

The effect of emotion type on accuracy was examined. Values of discrimination accuracy were entered in repeated measures non-parametric Friedman's ANOVA with emotion (Angry, Happy and Neutral) as within-subject factor. Results showed that emotion had a significant effect on accuracy (x^2 (2) =7.67, p=.022). Wilcoxon tests were used to follow up this finding. Non-parametric paired Wilcoxon tests compared angry to happy, angry to neutral and happy to neutral. A Bonferroni correction was applied, so all effects were reported at a .05/3=.016 level of significance. Results showed that accuracy was significantly higher for angry compared to neutral (T=775.00, p=.006, r=-.31) and happy compared to neutral (T=769.50, p=.002, r=-.36) faces. The effect of emotion type on bias was examined via repeated measures ANOVA because bias values were normally distributed. Results showed a marginally significant effect of emotion on response bias (F (2,144)=3.21, p=.043, η^2_p=.05). Pairwise comparisons indicated a tendency for participants to display higher bias to angry compared to happy (p=.078) but no other difference was significant. Means, medians and standard deviations of accuracy and bias values are presented in Table 8.1.

Table 8. 1. *Mean, median and SD for discrimination accuracy and response bias to facial expressions in the whole sample (N=73) and by gender.*

Facial Expression	Discrimination Accuracy			Response Bias		
	Boys	Girls	Total	Boys	Girls	Total
Angry						
Mean	.83	.86	.84	.40	.38	.39
Median	.90	.89	.90	.38	.33	.36
SD	.18	.11	.16	.22	.26	.23
Happy						
Mean	.84	.88	.86	.31	.29	.30
Median	.90	.91	.90	.29	.31	.29
SD	.17	.10	.15	.20	.18	.19
Neutral						
Mean	.79	.82	.80	.32	.30	.31
Median	.86	.89	.86	.27	.33	.26
SD	.23	.16	.21	.20	.21	.20

Note: Accuracy values range: -1≈ worse than chance, 0 ≈ chance, 1≈ better than chance. Response bias values range from 0 -1. Absence of bias ≈ 0, Presence of bias ≈ 1.

8.4.1.4 Correct classifications and misattribution patterns

Further analyses examined correct classifications and misattribution patterns (i.e. tendency to confuse one expression with another) for angry, happy and neutral facial expressions. Mean accuracy for all three facial expressions was 89.29% (SD=11.51%), suggesting that participants performed the task to a high standard. Friedman's ANOVA indicated no significant difference between the percent of angry face classified as neutral and the percent of happy faces classified as neutral (x^2 (1) =.000, p=1.00).

Table 8. 2. *Mean percent (SD) of trials classified correctly and misattributions (N=73).*

	Child Response		
Facial Expression	Angry	Happy	Neutral
Angry	**91.27(10.87)**	3.37(.5.69)	4.22(5.51)
Happy	3.97(6.02)	**90.59(10.90)**	4.54(6.39)
Neutral	8.05(15.50)	3.94(6.18)	**86.02(18.57)**

Note: In bold the vocal expressions classified correctly.

8.4.1.5 Intercorrelations between emotion processing measures

Spearman's correlations examined the relationship between accuracy and bias measures. Results are presented in Table 8.3. Accuracy scores to angry, happy and neutral faces were positively inter-correlated. Response bias to anger was negatively associated with bias to happy and neutral. Accuracy to neutral faces was positively associated with bias to neutral.

Table 8. 3. *Spearman's correlations (p value) for the emotion processing measures (N=73)*

	Accuracy Angry	Accuracy Happy	Accuracy Neutral	Bias Angry	Bias Happy	Bias Neutral
Accuracy Angry						
Accuracy Happy	**.69(.001)**					
Accuracy Neutral	**.82(.001)**	**.67(.001)**				
Bias Angry	.10(.366)	-.01(.909)	-.13(.290)			
Bias Happy	.08(.483)	.20(.077)	.15(.208)	**-.25(.036)**		
Bias Neutral	.15(.197)	.02(.892)	**.33(.005)**	**-.55(.001)**	-.14(.238)	-

8.4.2 Event Related Potentials (ERPs)

8.4.2.1 Preliminary analyses

8.4.2.1.1 The effect of child age and gender on amplitude and latency of ERPs

Pearson's correlations examined associations between child age and mean amplitude and latency values of the ERP components of interest. Results showed that child age, overall, was not associated with ERP components' amplitude and latency (Pearson's r from -.02 to .22 p>.05) except for central P1 amplitude to neutral faces (r=.25, p=.050), central P1 latency to happy faces (r=.30, p=.015) and parietal P1 latency to happy faces (r=.26, p=.037). Subsequent analyses were repeated controlling for child age for these ERPs.

Independent samples t-tests examined differences in ERPs amplitude between boys and girls. Results showed a significant difference in occipital N170 amplitude between boys and girls for angry [t (61) =2.54, p=.014], happy [t (61) =2.67, p=.010] and neutral [t (61) =2.58, p=.012] faces. There was also a significant difference in the central P3 amplitude for happy faces [t (61) =-2.05, p=.025], central early Slow Wave amplitude for neutral faces [t (61) =-1.88, p=.037], central late Slow Wave amplitude for happy faces [t (61) =-1.84, p=.045], parietal N170 amplitude for angry faces [t (61) =2.67, p=.016] and parietal N170 amplitude for neutral faces [t (61) =2.36, p=.022]. In all cases, amplitudes were increased (more negative for the N170) in girls compared to boys. There were no significant differences between boys and girls in ERPs' latency (p>.05). Gender effects should be interpreted with caution given the unequal distribution of gender in the sample. Subsequent analyses were repeated controlling for child gender for the above components.

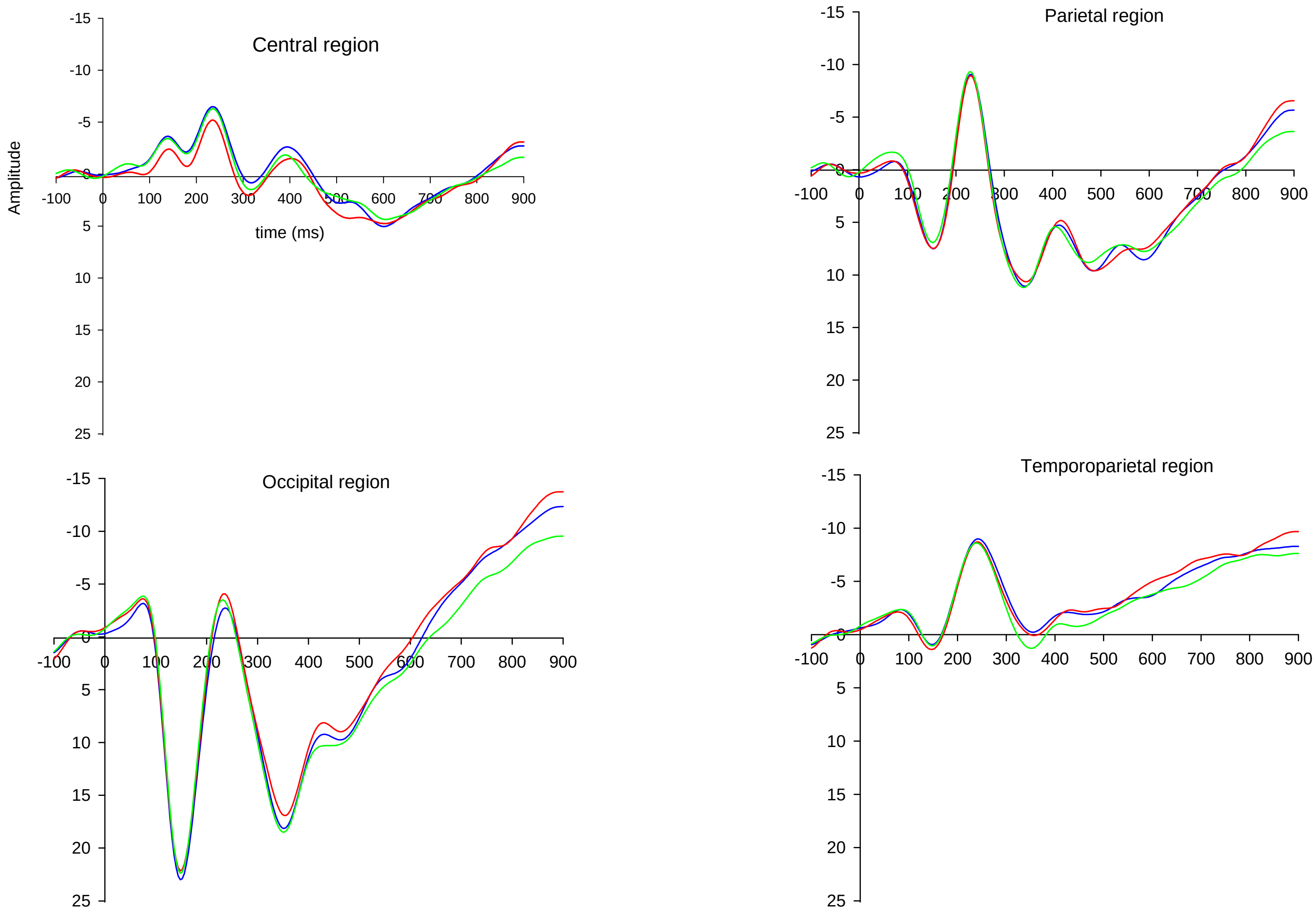


Figure 8. 3. Grand mean ERPs to angry, happy and neutral faces. Amplitude (μV) and time (ms) are marked at all regions with a pre-stimulus baseline of -100 ms. Scale is -15 to + 25 μV. Angry Happy Neutral

8.4.2.2 Main analyses

8.4.2.2.1 Emotion effects on Event Related Potentials to facial expressions

Figure 8.3 displays the grand mean ERPs to angry, happy and neutral faces. Repeated measures ANOVA with emotion type (Angry, Happy, Neutral) as within-subject factor were conducted to examine the main effect of emotion on amplitude and latency of the P1 and the N170 and amplitude of the P300 and the ESW and LSW in each region. Because the focus of the present study was on the ERP correlates of anger processing, simple planned contrasts compared the angry face condition with neutral and happy face condition.

Results revealed that central P1 amplitude was significantly larger for happy faces compared to angry faces. There was a tendency for enhanced central N170 amplitude to angry faces compared to happy faces. The N170 latency to angry faces was greater than to neutral faces in the parietal and temporoparietal region (p=.006). Finally, temporoparietal P3 amplitude to angry faces was significantly smaller than amplitude to neutral faces. It should be noted, however, the P3 was not evident in that region. Results did not change after controlling for child age and gender for those components which showed age and gender effects. After Bonferroni correction for multiple comparisons was applied, with an accepted alpha of .05/40=.001 adopted, the above findings did not survive correction. A main effect of emotion on temporoparietal N170 latency (faster to neutral than angry faces) was close to significance (p=.006). It should be noted, however, that these differences in latency (e.g. 6 ms) were very small, and they should be interpreted with caution especially given the sampling rate (250 Hz). Results are summarised in Tables 8.4 and 8.5.

Table 8. 4 *Effects of emotion on mean amplitude (µV) of the targeted ERP components to facial expressions at the four scalp regions (N=63).*

	P1		N170		P3		Early Slow Wave		Late Slow Wave	
Region	A vs H	A vs N	A vs H	A vs N	A vs H	A vs N	A vs N	A vs H	A vs N	A vs H
Central	0.70 vs. 1.96	0.70 vs. 0.72	-9.53 vs.-8.18	-9.53 vs.-9.26	-1.97 vs.-.84	-1.97 vs.-0.87	1.37 vs. 2.39	1.37 vs. 1.71	3.73 vs. 4.55	3.73 vs. 3.39
F value	4.31	.001	3.59	.16	2.62	1.86	1.83	.16	.90	.20
Significance (p)	**.042**	.979	**.063**	.693	.111	.178	.180	.691	.346	.656
Occipital	24.79 vs.24.05	24.79 vs .24.23	-6.26 vs.-7.66	-6.26 vs.-7.10	13.42vs.12.76	13.42vs.14.24	8.29 vs. 7.92	8.29 vs. 9.23	2.98 vs. 2.44	2.98 vs. 3.89
F value	1.10	.72	3.11	.94	.61	.64	.14	.83	.30	.87
Significance	.298	.399	.082	.335	.436	.424	.706	.364	.582	.354
Parietal	9.44 vs. 9.93	9.44 vs. 8.99	-11.19 vs. -.11.25	-11.19 vs. -11.78	7.42 vs. 7.41	7.41 vs. 7.73	8.38 vs. 8.49	8.38 vs. 8.22	7.61 vs. 7.79	7.61 vs. 7.43
F value	.41	.38	.001	.59	.000	.101	.01	.02	.03	.04
Significance	.524	.539	.948	.446	.995	.751	.902	.880	.862	.846
Temporoparietal	2.58 vs .3.17	2.58 vs .2.70	-11.16 vs. -10.99	-11.16 vs. -10.95	-1.41 vs.-0.92	-1.41 vs. 0.00	-2.30 vs.-2.29	-2.30 vs.-1.21	-3.57 vs.-3.87	-3.57 vs.-3.23
F value	1.51	.07	.06	.11	.57	4.42	.000	2.42	.14	.23
Significance	.223	.791	.800	.732	.451	**.040**	.989	.125	.704	.632

Note 1: A: Angry, H: Happy, N: Neutral. Note 2: Controlling for child age for central P1 amplitude did not change the results. Note 3: Results did not change after controlling for child gender for Occipital N170 amplitude, Central P3 amplitude, central early and late Slow Wave amplitude and parietal occipital N170 amplitude.

Table 8. 5. *Effects of emotion on latency (ms) of the targeted ERP components to facial expressions at the four scalp regions (N=63).*

	P1 latency		N170 latency	
Region	A vs H	A vs N	A vs H	A vs N
Central	150.45 vs. 149.24	150.45 vs. 151.81	236.85 vs. 234.86	236.85 vs. 231.54
F value	.09	.10	.26	2.45
Significance (p value)	.754	.750	.606	.122
Occipital	150.01 vs. 150.27	150.01 vs. 151.33	241.19 vs. 240.43	241.19 vs. 237.65
F value	.07	1.92	.20	2.97
Significance	.785	.170	.655	.089
Parietal	151.56 vs. 150.27	151.56 vs. 152.34	234.74 vs. 233.79	234.74 vs. 228.67
F value	.30	.10	.21	7.01
Significance	.580	.750	.647	**.010**
Temporoparietal	143.25 vs. 142.71	143.25 vs. 144.95	248.68 vs. 245.08	248.68 vs. 242.09
F value	.06	.47	2.94	7.95
Significance	.797	.492	.091	**.006**

Note 1: A: Angry, H: Hapy, N: Neutral. *Note 2:* Controlling for child age for central and parietal occipital P1 latency did not change the results

8.4.2.2.2 Laterality effects on Event Related Potentials to facial expressions

Further analyses explored possible laterality effects on the ERPs. A focused analysis was conducted with early latency ERPs (P1, N170). The right and left hemisphere were compared after combining sites per region belonging to each hemisphere for the P1 and N170. As in Study 4, the following groupings were created: Right Central (sites 4 and 10), Right Parietal (sites 12, 24), Right Occipital (sites 37, 38), Right Temporoparietal (sites 22, 47) –see Figure 8.2. For the left hemisphere the following groupings were created: Left Central (sites 16, 6), Left Parietal (sites 14, 26), Left Occipital (sites 39, 40) and Left Temporoparietal (sites 28, 53). The above groupings of electro sites were entered in a repeated measures 2 (laterality: Right, Left) x 3 (emotion type: Angry, Happy, Neutral) design ANOVA for each ERP separately with emotion type and laterality as within-subject factors. Because the focus was on anger processing, simple planned contrasts compared the angry face condition with neutral and happy face condition.

On the whole, right and left hemisphere ERPs were not associated with child age with few exceptions: left parietal P1 latency to happy faces ($r=.27$, $p=.031$), right central P1 amplitude to neutral faces ($r=.26$, $p=.040$), right ($r=.32$, $p=.009$) and left ($r=.36$, $p=.004$) central P1 latency to happy faces and left temporoparietal P1 latency to happy faces ($r=.30$, $p=.014$). Gender differences in right and left hemisphere ERPs were examined with independent samples t-tests. Results showed significant differences between males and females. In summary, girls showed enhanced N170 amplitudes to angry, happy and neutral faces than boys in the right parietal and occipital regions. Boys showed greater P1 amplitude to happy faces than girls in the right parietal region [$t(61) = 2.15$, $p=.036$][6]. Therefore, analyses were repeated covarying for age and gender for the above components.

Results revealed significant laterality effects on early latency ERPs In particular, P1 and N170 amplitudes were larger in the right compared to left hemisphere across regions, although in the occipital region N170 amplitude was larger to the left than right hemisphere. In addition, P100 and N170 latencies were shorter in the right compared to the left hemisphere in the central and occipital region but this effect was not present in the temporoparietal and parietal regions. There was a significant emotion x laterality interaction effect on the parietal N170 amplitude and occipital N170 latency; however, these differences were small. Temporoparietal N170 was enhanced for neutral compared to angry faces in the right compared to the left hemisphere. After controlling for child age, temporoparietal P100 latency was smaller for angry but not happy faces in the right compared to the left hemisphere. Results are presented in Table 8.6.

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[6] Supplementary details available from the author

Table 8. 6. *Effects of 3 (emotion) by 2 (laterality) ANOVA on ERPs amplitude and latency*

Component	Effect	Contrast	Details	F-value	Significance
Central					
P100 amp	Emotion	H vs. A	2.07 vs. 0.84	4.12	.047
	Lateral	R vs. L	1.55 vs. 0.94	6.26	.015
P100 lat	Lateral	R vs. L	143.52 vs.150.62	14.96	.000
N170 amp	Lateral	R vs. L	-9.83 vs. -8.55	13.22	.001
N170 lat	Lateral	R vs. L	229.35 vs . 235.19	7.41	.008
Parietal					
P100 amp	Lateral	R vs. L	12.40 vs. 7.96	48.20	.000
P100 lat	-	-	-	-	*ns.*
N170 amp	Emo x Lat	H vs. A by R vs. L	H: -10.96 vs.-11.08 A:-10.31 vs .-11.31	4.88	.031
N170 lat	Emotion	A vs. N	234.70 vs .228.31	8.48	.005
Occipital					
P100 amp	Lateral	R vs. L	28.06 vs .20.07	52.28	.000
P100 lat	Lateral	R vs. L	149.44 vs .151.64	7.82	.007
N170 amp	Lateral	L vs. R	-8.20 vs .-5.81	9.55	.003
N170 lat	Emo x Lat	H vs. A by R vs. L	H: 240.09 vs . 240.76 A: 243.55 vs . 238.82	5.70	.020
Temporoparietal					
P100 amp	Lateral	R vs. L	3.68 vs.1.94	19.83	.000
P100 lat	-	-	-	-	*ns.*
N170 amp	Lateral	R vs. L	-12.31 vs.-9.74	19.23	.000
	Emo x Lat	N vs. A by R vs. L	N:-12.76 vs. -9.55 A:-11.90 vs. -9.99	12.01	.001
N170 lat	Emotion	N vs. A	248.68 vs .242.09	7.94	.006

Abbreviations: A: Angry, H: Happy, N: Neutral, Emo: Emotion. Lat: Lateral, amp: amplitude, lat: Latency. After controlling for child age: Central P100 amp: non sig effects or interactions. Temp P100 lat: Em x Lat (p=.003), A vs H by R vs L: H: 141.58 vs 143.84, A: 140.19 vs 146.31.After controlling for child gender: effects on Par N170 amp did not hold. Laterality effect on occipital N170 amp became less sig (p=.016).

8.4.3 Psychopathology

A second aim of the study was to explore associations between ERP markers of facial anger processing and behaviour problems in children. Details regarding child symptoms in the whole sample are provided in Section 6.2.

8.4.3.1. Child Psychopathology and Performance

Performance was at ceiling levels as the present study was designed to pick up individual differences at the electrophysiological rather than the performance level. Spearman's correlations examined associations between child psychopathology and performance. Results showed a negative relationship between accuracy for angry and neutral faces and child hyperactivity and between conduct problems and accuracy for happy faces ($p<.05$) (see Appendix E).

8.4.3.2 Child Psychopathology and Event Related Potentials

Pearson's correlations examined the relationship between the ERPs and child psychopathology. Because there were no significant emotion effects on the ERP components of interest, further analyses included all ERP components across all regions to examine associations between behaviour problems and general face processing. Analyses controlled for child age because child age was associated with amplitude for some ERPs.

Results showed a strong negative association between child internalising symptoms, including anxiety and depression, and mean P3, ESW and LSW amplitude across emotion types and scalp regions. In addition, hyperactivity and conduct problems were negatively associated with occipital P1, P3 and ESW mean amplitude to neutral faces, parietal P1, P3 and ESW mean amplitude to neutral faces and central P1 amplitude, P1 and N170 latency to neutral faces. Conduct problems were negatively associated with central P1 latency to neutral faces. Finally, there was a positive association between hyperactivity and temporoparietal N170 amplitude to happy and angry faces and temporoparietal P1 amplitude to angry faces. Results are presented in Tables 8.7-8.10. These associations were not specific to a particular emotion type and given the lack of emotion effects on ERPs, they may suggest general face processing rather than emotion-specific difficulties. When a Bonferroni correction was applied with an alpha level of .05/105=.0005 adopted, the above associations did not remain significant.

8.4.4 Results Summary

Children performed the emotion identification task at high levels of accuracy. Children were more accurate in discriminating angry than neutral facial expressions and showed higher tendency to attribute anger than happiness to facial expressions. ERP analyses showed few emotion effects on ERPs. For instance, children presented a tendency for enhanced central N170 amplitude to angry compared with happy faces. They also presented larger temporoparietal N170 latency to angry compared to neutral faces. However, these emotion effects did not survive correction for multiple testing. Therefore, associations with psychopathology focused on ERPs across emotions and regions reflecting general face processing than emotion-specific processing. Results showed negative associations between anxiety/depression and P3 and Slow Wave amplitudes. There were also negative associations between hyperactivity/conduct problems and P1 and P3 amplitudes to neutral facial expressions but none were significant after controlling for multiple comparisons. Because no clear emotion effects on ERPs emerged, the present study did not investigate further parent characteristics in the absence of a rationale linking children's general face processing with parent characteristics[7]

[7] As in Study 4, because of the high levels of performance required for reliable ERPs, it was not expected that performance would be associated with the ERPs. Associations between performance and ERPs are presented in Appendix E. Few marginal associations emerged between performance and ERPs across regions

Table 8. 7. *Partial Pearson's correlations between child symptoms and ERPs at the central region after controlling for child age.*

	Hyperactivity	Conduct Problems	Anxiety	Depression	Emotion Dysregulation
P100 amplitude					
Angry	-.03(.826)	-.11(.385)	.04(.770)	-.00(.972)	-.02(.868)
Happy	-.02(.862)	-.01(.921)	-.07(.604)	.04(.716)	.03(.847)
Neutral	-.25(.059)	-.09(.472)	-.16(.241)	-.25(.062)	-.12(.355)
P100 latency					
Angry	-.05(.687)	-.06(.642)	.10(.432)	.03(.817)	.02(.856)
Happy	-.20(.124)	-.07(.596)	.04(.757)	.09(.497)	-.00(.981)
Neutral	**-.30(.019)**	**-.34(.010)**	-.20(.115)	-.25(.056)	**-.27(.040)**
N170 amplitude					
Angry	.15(.246)	.02(.875)	.01(.916)	.11(.374)	-.00(.992)
Happy	.09(.512)	-.05(.715)	-.04(.751)	.07(.636)	-.09(.462)
Neutral	.08(.542)	-.03(.836)	-.16(.238)	-.15(.261)	-.12(.365)
N170 latency					
Angry	-.04(.780)	-.05(.684)	.12(.352)	.09(.465)	.06(.671)
Happy	-.16(.230)	-.04(.745)	.05(.722)	.14(.278)	.03(.806)
Neutral	**-.27(.038)**	-.16(.223)	-.05(.698)	-.09(.459)	-.10(.437)
P300 amplitude					
Angry	-.07(.596)	-.14(.298)	**-.29(.024)**	-.25(.055)	-.20(.122)
Happy	-.14(.281)	-.16(.229)	-.24(.067)	**-.28(.033)**	-.24(.071)
Neutral	-.21(.109)	-.19(.166)	**-.27(.038)**	**-.33(.011)**	**-.30(.023)**
Early SW amplitude					
Angry	-.09(.512)	-.12(.356)	**-.30(.018)**	**-.28(.031)**	-.16(.209)
Happy	-.14(.287)	-.14(.299)	**-.29(.029)**	**-.27(.039)**	-.24(.066)
Neutral	-.24(.068)	-.23(.086)	**-.34(.009)**	**-.39(.003)**	**-.32(.015)**
Late SW amplitude					
Angry	-.09(.455)	-.14.(296)	-.25(.062)	-.18(.170)	-.20(.119)
Happy	-.11(.394)	-.07.(.574)	**-.26(.049)**	-.24(.065)	-.19(.136)
Neutral	-.19(.145)	-.14.(279)	**-.34(.008)**	**-.33(.012)**	**-.26(.048)**

Table 8. 8. *Partial Pearson's correlations between child symptoms and ERPs at the parietal region after controlling for child age*

	Hyperactivity	Conduct Problems	Anxiety	Depression	Emotion Dysregulation
P100 amplitude					
Angry	-.13(.323)	-.12(.355)	-.02(.852)	.04(.771)	-.11(.384)
Happy	-.16(.238)	-.05(.690)	-.02(.858)	.06(.635)	-.11(.385)
Neutral	**-.23(.037)**	-.02(.850)	-.08(.544)	-.05(.681)	-.19(.158)
P100 latency					
Angry	-.08(.531)	-.03(.831)	-.22(.092)	-.17(.194)	-.04(.758)
Happy	-.06(.673)	.12(.372)	-.07(.631)	-.02(.895)	.11(.390)
Neutral	-.07(.599)	-.09(.459)	**-.30(.021)**	-.23(.075)	-.19(.142)
N170 amplitude					
Angry	.18(.172)	.15(.259)	.07(.607)	.17(.206)	.10(.429)
Happy	.15(.266)	.11(.404)	.03(.842)	.14(.274)	.04(.740)
Neutral	.13(.319)	.20(.128)	-.01(.925)	.06(.631)	.07(.593)
N170 latency					
Angry	.04(.738)	.05(.685)	.07(.613)	.02(.866)	.09(.517)
Happy	-.06(.638)	.05(.725)	-.00(.962)	.09(.482)	.20(.121)
Neutral	-.15(.252)	-.08(.553)	-.04(.762)	-.06(.671)	.02(.874)
P300 amplitude					
Angry	-.12(.354)	-.20(.125)	**-.27(.041)**	-.20(.131)	-.21(.102)
Happy	-.20(.119)	**-.28(.034)**	**-.27(.039)**	-.27(.356)	**-.28(.034)**
Neutral	**-.26(.048)**	-.25(.054)	**-.29(.024)**	**-.30(.019)**	**-.33(.011)**
Early SW amplitude					
Angry	-.13(.334)	-.21(.102)	**-.32(.015)**	**-.27(.042)**	-.19(.157)
Happy	-.16(.214)	-.22(.088)	**-.30(.020)**	**-.28(.034)**	**-.28(.031)**
Neutral	**-.27(.042)**	**-.27(.040)**	**-.39(.002)**	**-.41(.001)**	**-.34(.009)**
Late SW amplitude					
Angry	-.10(.429)	-.22(.089)	-.25(.056)	-.15(.255)	-.20(.120)
Happy	-.09(.520)	-.15(.270)	**-.30(.021)**	**-.26(.044)**	-.18(.170)
Neutral	-.17(.192)	-.22(.102)	**-.40(.001)**	**-.37(.004)**	**-.25(.062)**

Table 8.9. *Partial Pearson's correlations between child symptoms and ERPs at the temporoparietal region after controlling for child age*

	Hyperactivity	Conduct Problems	Anxiety	Depression	Emotion Dysregulation
P100 amplitude					
Angry	**.29(.025)**	.08(.537)	.01(.942)	.03(.839)	.13(.342)
Happy	.13(.313)	-.02(.893)	.00(.973)	-.00(.963)	.04(.787)
Neutral	-.02(.872)	.02(.860)	-.24(.069)	**-.27(.036)**	-.03(.824)
P100 latency					
Angry	.14(.293)	.00(.960)	.01(.908)	.02(.890)	.08(.557)
Happy	.04(.775)	.02(.872)	-.10(.447)	-.08(.563)	.08(.542)
Neutral	.02(.846)	-.00(.953)	-.12(.376)	-.20(.119)	-.11(.388)
N170 amplitude					
Angry	**.33(.010)**	.15(.256)	.02(.857)	.03(.831)	.09(.464)
Happy	**.28(.031)**	.10(.445)	-.05(.687)	-.01(.923)	.07(.602)
Neutral	.20(.128)	.13(.332)	-.09(.518)	-.08(.540)	-.01(.937)
N170 latency					
Angry	.06(.674)	.10(.437)	.07(.633)	.09(.510)	.19(.154)
Happy	-.09(.460)	-.02(.882)	-.07(.614)	-.00(.963)	-.01(.925)
Neutral	-.22(.088)	-.02(.872)	-.08(.533)	-.09(.499)	-.04(.739)
P300 amplitude					
Angry	.04(.746)	-.03(.806)	**-.26(.049)**	-.23(.085)	-.13(.336)
Happy	-.02(.848)	-.13(.317)	-.26(.050)	-.27(.036)	-.16(.236)
Neutral	-.14(.301)	-.12(.364)	**-.30(.021)**	-.28(.029)	**-.26(.043)**
Early SW amplitude					
Angry	.00(.957)	-.03(.853)	-.30(.018)	**-.25(.061)**	-.10(.411)
Happy	-.03(.826)	-.09(.521)	**-.28(.034)**	**-.27(.042)**	-.15(.258)
Neutral	-.14(.302)	-.13(.343)	**-.37(.004)**	**-.32(.013)**	-.25(.053)
Late SW amplitude					
Angry	-.00(.992)	-.02(.914)	**-.26(.049)**	-.15(.246)	-.13(.312)
Happy	-.03(.861)	-.04(.798)	-.25(.052)	-.22(.096)	-.12(.383)
Neutral	-.10(.426)	-.08(.539)	**-.36(.005)**	-.25(.052)	-.20(.129)

Table 8. 10. *Partial Pearson's correlations between child symptoms and ERPs at the occipital region after controlling for child age*

	Hyperactivity	Conduct problems	Anxiety	Depression	Emotion Dysregulation
P100 amplitude					
Angry	-.13(.328)	-.15(.265)	-.08(.551)	-.02(.880)	-.16(.238)
Happy	-.18(.185)	-.16(.242)	-.02(.855)	-.00(.994)	-.18(.167)
Neutral	**-.28(.037)**	-.11(.406)	-.11(.403)	-.09(.490)	-.19(.138)
P100 latency					
Angry	.00(.979)	.19(.143)	-.16(.386)	-.04(.775)	.10(.421)
Happy	.01(.925)	.09(.474)	-.17(.204)	-.03(.799)	.03(.793)
Neutral	.05(.681)	.10(.444)	-.18(.165)	-.11(.393)	.00(.995)
N170 amplitude					
Angry	.22(.095)	**.27(.037)**	.01(.920)	-.01(.930)	.22(.098)
Happy	.15(.243)	.22(.094)	-.06(.667)	-.02(.862)	.16(.225)
Neutral	.12(.380)	**.30(.020)**	-.09(.895)	-.02(.884)	.15(.262)
N170 latency					
Angry	.03(.827)	.09(.487)	-.11(.403)	-.12(.390)	.04(.770)
Happy	-.07(.595)	.02(.858)	-.08(.537)	-.13(.344)	-.03(.847)
Neutral	-.12(.380)	.05(.710)	-.07(.606)	-.11(.407)	-.04(.776)
P300 amplitude					
Angry	-.20(.112)	-.21(.110)	**-.27(.042)**	-.23(.081)	-.21(.103)
Happy	-.24(.073)	**-.27(.039)**	**-.32(.013)**	**-.32(.013)**	-.23(.076)
Neutral	**-.34(.008)**	-.25(.054)	**-.33(.010)**	**-.30(.019)**	**-.32(.014)**
Early SW amplitude					
Angry	-.17(.205)	-.23(.078)	**-.32(.014)**	**-.26(.049)**	-.19(.155)
Happy	-.13(.331)	-.19(.136)	**-.32(.015)**	**-.30(.021)**	-.22(.100)
Neutral	**-.27(.041)**	**-.27(.040)**	**-.43(.001)**	**-.40(.002)**	**-.32(.015)**
Late SW amplitude					
Angry	-.11(.390)	-.23(.082)	-.25(.053)	-.15(.273)	-.22(.099)
Happy	-.08(.555)	-.18(.183)	**-.32(.014)**	**-.27(.037)**	-.18(.195)
Neutral	-.18(.184)	**-.27(.040)**	**-.43(.001)**	**-.34(.009)**	**-.26(.046)**

8.5 Discussion

The present study investigated the neural correlates of facial anger processing in typically developing 6- to 11-year-old children and explored associations between child behaviour problems and neural markers of face processing.

The facial emotion recognition task worked well for the purposes of the present study. Children were more accurate to recognise angry compared to neutral and happy compared to neutral facial expressions and showed a tendency for a higher bias to angry relative to happy expressions. High accuracy rates for angry faces are consistent with other developmental studies in similar age groups (Vicari et al., 2000) and the previous studies of the thesis.

First, the ERPs observed in the present study were consistent with the developmental literature in face processing and facial emotion processing. The P1 (150 ms) was observed in parietal and occipital regions. The N170 (240 ms) was also evident in the parietal, occipital and temporoparietal region. Latency ranges are consistent with the developmental literature showing delayed P1 (100-160 ms) and N170 (170-270 ms) in school-aged children (Batty & Taylor, 2006; Dennis et al., 2009; Todd et al., 2008). In adults, these components, maximal over posterior temporal and occipital sites, peaked as early as 94 ms (P1) and 140 ms (N170) (Batty & Taylor, 2003). The P3, evident around 350 ms, was largest at parietal and occipital regions and less readily observed at central and temporal sites. A positive slow wave (450 ms) was observed at occipital and parietal regions and a negative driving slow wave in central and temporoparietal regions (520-610 ms). Developmental research using facial emotional stimuli have observed central negative components (250-500 ms) and frontocentral negativity (300 and 390 ms) in 4- to 15-year-olds (Batty & Taylor, 2006) and also late frontal positive components (750-850 ms) in 4- to 6-year-olds (Todd et al., 2008) and temporal P3 (300-400 ms) components in adolescents (Williams et al., 2008).

In this study, neural markers of face processing did not differ with respect to emotion condition in 6- to 11-year-olds. Some observations with regard to this finding are of note.

This pattern of results is consistent with developmental ERP studies showing that a dissociable effect of emotion condition on child ERP data (and more specifically the N170) does not emerge until adolescence, around 14 to 15 years, and is not clearly evident in younger age groups (Batty & Taylor, 2006; review by Taylor et al., 2004). When emotion effects have been observed in younger children, they were limited to the P1 component, indexing global visual processing of faces, and not the 'face-specific' N170 component, reflecting finer discrimination of facial features (Batty & Taylor, 2006; Dennis et al., 2009; Todd et al., 2008).

Findings from the present study provide confirmatory evidence for a protracted maturational course of the neural processing involved in the perception of emotion from human faces, with finer grained processing possibly emerging after 11 years of age. This is consistent with behavioural studies showing increased emotion recognition accuracy in adolescence compared to middle childhood (Montirosso et al., 2010; Tonks et al., 2007). Absence of emotion modulation of ERPs evoked by human faces has been shown by other developmental studies (Battaglia et al., 2005; de Haan et al., 1998; Leppänen, Moulson, et al., 2007) and adult studies (Eimer et al., 2003; Herrmann et al., 2002; Pizzagalli et al., 2002), suggesting that the neural mechanisms responsible for emotion perception from faces may continue to develop throughout adulthood, thus making it difficult to establish a truly 'mature' endpoint.

In addition, where tendencies for emotion effects were observed in the present study, these related to enhanced N170 and P3 amplitudes, to negative (i.e. angry) compared to positive (i.e. happy) facial expressions. Also, temporoparietal N170 latency was longer for angry compared to neutral facial expressions in children. Enhanced neural processing of negative compared to positive emotion has consistently been found in infants and children (Batty & Taylor, 2006; Grossmann et al., 2007) as in adults (Schupp, Junghofer, Weike, & Hamm, 2004). However, results in the present study are difficult to interpret in a meaningful way, given the small differences and the limitations of the sampling rate.

Finally, emotion effects on the N170, indexing finer discrimination of facial configuration, may be driven by properties of the stimuli, such as intensity of facial stimuli. Facial stimuli in the present study (Ekman & Friesen, 1976) consisted of grayscale, static images which are, to some extent, unecological relative to coloured, dynamic facial stimuli of varying intensity encountered in real-life social interactions. For example, research has shown a significant increase in amplitude of the N170 by intensity but not by type of emotion of facial expression (Sprengelmeyer & Jentzsch, 2006). Similarly, a recent study found that whereas the P1 was associated with the correct detection of facial emotion, the N170 was linked with the assessment of the intensity level of the expression (Utama et al., 2009). This explanation is compatible with findings showing emotion effects on children's early latency ERPs, only under the condition of faces being presented with detailed facial features (as is the case of stimuli of varying intensity) than global face characteristics (Vlamings et al., 2010).

From a methodological viewpoint it should be noted that the present study adopted an explicit emotion identification task for consistency with Study 4. The neural processing of emotional faces can be sensitive to task demands in children (review by Taylor et al., 2004) and adults (Critchley et al., 2000). Previous studies showing emotion effects on children's

ERPs used implicit emotion recognition paradigms (Batty & Taylor, 2006; Vlamings et al., 2010) or complex attention tasks (Dennis et al., 2009; Todd et al., 2008), such as identifying other objects among faces, whereas the present task required directed attention to the facial expression for accurate identification of the emotion. Therefore, it is possible that emotion effects on ERPs to facial expressions may be present in implicit but not explicit processing of faces (Batty & Taylor, 2003; Vuilleumier & Schwartz, 2001). Also, frontal sites were excluded from the study due to ocular artifacts mainly affecting frontal sites. The role of the orbitofrontal cortex has been highlighted in emotion processing tasks requiring direct attention to facial expressions (Adolphs, 2002).

In summary, in light of previous developmental research and methodological considerations, the absence of emotion effects on the ERPs in this study was not surprising. It should also be acknowledged that a mean amplitude method within a specified time window selected for quantifying the ERP signal in the present study may have produced misleading results. An alternative method would be to follow a *peak-to-peak amplitude* method which measures the mean amplitude not in relation to the baseline but in relation to a neighbouring peak or trough. This measurement has a number of advantages including the fact that the ERP signal can remain unaffected by noise at the baseline (see section 5.1.4 for more details).

In regards to laterality effects, the P1 and N170 were larger in amplitude and shorter in latency in the right compared to the left hemisphere in this study. Lateralisation effects on ERPs in favour of the right hemisphere are consistent with findings from other adult (Adolphs, 2002; Borod et al., 1998) and child (de Haan et al., 2004; de Haan et al., 1998) studies. Despite the few emotion x laterality interaction effects on the ERPs these effects were not strong, apart from the temporoparietal N170 which was more enhanced for neutral compared to angry faces in the right compared to the left hemisphere. De Haan and colleagues (1998) showed that N170 amplitudes were larger for negative (i.e. angry and fearful) but not happy faces in the right compared to left hemisphere.

A second aim of the study was to examine the relationship between neural markers of facial anger processing and child behaviour problems. Because ERP components were not sensitive to emotion in this sample of school-aged children, it was not possible to further investigate associations between ERP markers of facial anger processing and child behaviour. The study, therefore, explored general face processing and links to child psychopathology.

Hyperactivity was negatively associated with P1 amplitude and latency and also central N170 latency to neutral faces, possibly suggesting that hyperactive children may show impaired visual perception of facial, not necessarily emotional expressions. There is evidence that early sensory and perceptual processing of visual stimuli may be impaired in ADHD (review by Barry et al., 2003). For example, ERP studies have uncovered abnormalities in visual information processing in ADHD children compared to controls (Brandeis et al., 1998; Jonkman et al., 1997a; Jonkman et al., 2004). Reduced latencies of early components, such as P2 at visual tasks, have also been found in individuals with ADHD, linked to rapid and atypical detection of stimuli as part of an impulsive style of visual information processing (Sunohara et al., 1999). Results from the present study showed that impairments in early perceptual analysis of visual stimuli, as reflected by reduced early latency ERPs, may possibly extend to socially relevant stimuli, such as human faces. Alternatively, children with hyperactivity may process neutral stimuli differently.

Although the present study did not include a control attention task of non-face stimuli to test in a more robust way the specificity of this neural impairment to facial stimuli, the developmental literature has consistently shown that during childhood early latency ERPs are differentially sensitive to human faces compared to non-face stimuli (i.e. objects) and faces that are not human (i.e. monkey faces) (de Haan et al., 2002; Pascalis, Demont, de Haan, & Campbell, 2001; Pascalis & Slater, 2004). Future research should aim to incorporate an attention task, alongside an emotion recognition task, to disentangle more directly influences of visual attention on face processing.

In summary, poor understanding of others' facial expressions in children with hyperactivity might be due to a rapid, inattentive style of processing faces. Given the nature of the ERPs, this study did not support previous ERP research showing facial anger processing deficits in adolescents with diagnoses of ADHD compared to controls (Williams et al., 2008). Children in this study were a community sample with enriched levels of hyperactivity symptoms via recruitment from clinical services. Future research should employ a group design to investigate this issue, after isolating a neural marker of facial anger processing.

In regards to comorbid conditions, conduct problems showed limited associations with late latency ERPs, such as the P300 and Slow Wave, to neutral facial expressions in posterior occipito-parietal sites. Conduct problems were also positively associated with N170 amplitudes to angry faces in occipital sites, possibly suggesting enhanced perceptual processing of anger. Associations, however, were not strong or anger-specific.

Finally, the present study showed a consistent pattern of negative associations between internalising symptoms (anxiety and depression) and the P300 and Slow Wave (SW) amplitude across regions, although these associations did not survive Bonferroni correction. The P3 in middle childhood is hypothesised to reflect attentional engagement and visual working memory (Nelson & McCleery, 2008) and a frontocentral negative component, peaking 400-800 ms after stimulus onset, is thought to reflect attention and recognition memory during face processing in infants (de Haan & Nelson, 1997; DeBoer et al., 2005). A negative slow wave (800-1700 ms) has been linked to detection of novelty during face processing in infants (Nelson, 1996).

In light of the above interpretation, the negative association found in this study between internalising symptoms and P3 amplitudes to facial expressions might possibly suggest difficulties in attentional engagement and visual working memory during face processing in children with internalising symptoms. This is a novel finding given the limited ERP research with facial stimuli in developmental populations with anxiety and depression, although it should be acknowledged that these associations were not strong. Findings from this study are compatible with recent studies in adults showing frontocentral novelty P3 reduction in depressed patients compared to controls in novelty oddball tasks (Tenke, Kayser, Stewart, & Bruder, 2010). Results are also consistent with previous behavioural research showing that increased childhood anxiety was associated with decreased ability to discriminate facial expressions (Richards et al., 2007). However, it has also been found that children of parents with depression, who were at risk for socioemotional difficulties, showed larger anterior P3 amplitude in an affective Posner task, suggesting that children engaged more processing resources to perform the task. The authors interpreted this finding as reflecting difficulties in children's emotion regulation (Perez-Edgar et al., 2006).

In summary, findings of this study were consistent with previous research indicating an extended maturational course of neural responses to facial emotion. In addition, the present study showed general face processing difficulties, as reflected by ERPs, in children with internalising symptoms. In summary, a neural marker of anger processing observed in Study 4 did not span across modalities (facial/vocal) but was specific to vocal expressions. This further highlights the salient role of vocal emotional signals during childhood.

Chapter 9. General Discussion

9.1 Chapter Overview

The present chapter will provide an overview of the main findings from the current programme of research. Subsequently, this chapter will present a discussion on the theoretical implications and the integration of the findings with developmental theories of facial and vocal emotion processing and also theories of child psychopathology and emotion processing. The chapter will highlight the original contribution of the thesis to the existing knowledge and discuss the clinical implications of the results. This will be followed by a reflection on the limitations of the present research alongside the directions for future research.

9.2 Overview of the Main Findings

The present thesis can be seen as consisting of two sections; one providing a behavioural and the second offering an electrophysiological exploration into emotion processing in children. The main findings of the first, behavioural, part of the thesis can be summarised as follows:

First, overall, preschool children presented reasonably high accuracy rates in recognising facial and vocal emotional expressions. Importantly, this was the case for two different sets of vocal stimuli; one containing linguistic and the other non-linguistic stimuli. These findings indicate that vocal channels of presentation can be an effective means for communicating emotion in this young age group. School-aged children also performed at reasonably high accuracy at facial and vocal expression recognition with both sets of stimuli. Both Study 1 and Study 3 showed that recognition accuracy was higher for angry compared to happy and sad facial and vocal expressions, suggesting some consistency across studies in emotion-specific patterns of recognition. Anger seems to be the emotion that is recognised with higher accuracy by children. In addition, recognition accuracy improved with increasing intensity levels across studies. Gender effects on recognition accuracy were not observed in any study.

Second, overall, preschool and school-aged children displayed low rates of response bias to facial and vocal emotional expressions. The assessment of response bias is useful because it provides an opportunity to examine the nature of the inference process (Banse & Scherer, 1996). Generally, children presented a low tendency to confuse emotions because recognition accuracy for each emotional expression was high. Both Study 1 and Study 3 showed a consistent pattern of emotion effects on bias; response bias was higher for sad compared to angry and happy facial and vocal expressions. This suggests that participants presented a higher tendency to attribute sadness compared to happiness and anger (to facial and vocal expressions) when uncertain of the correct response.

Third, developmental patterns in recognition accuracy could be observed. Preschoolers were less accurate in recognising facial emotional expressions compared to all other age groups, suggesting that the preschool years constitute an important developmental period for the ability to recognise emotional expressions. In addition, 10-year-olds performed as accurately as adults in recognising facial expressions. However, 10-year-olds did not perform as accurately as adults in recognising vocal expressions, suggesting that an adult-like pattern of recognising emotion from prosody does not emerge until later than 10 years of age. In addition, preschoolers presented lower accuracy compared to older age groups in discriminating high (75% and 100%) intensity facial expressions; however, for low (50%) intensity expressions they did not differ from 8-year-olds. A developmental pattern in bias was also evident in Study 3. In particular, preschoolers presented higher bias to facial expressions compared to older (8 and 10-year-old) children. Similarly, younger (6-year-old) children presented higher bias to vocal expressions compared to older (10-year-old) children and adults. The above findings suggest that while accuracy increases, bias decreases with development as children become more competent at emotion recognition.

Fourth, accuracy for facial and vocal expressions was strongly positively associated in both Study 1 and Study 2. This suggests that facial and vocal emotion recognition skills develop in parallel during development, leading to successful bimodal emotion processing (Banziger et al., 2009). In addition, emotion effects on accuracy were similar across modalities (face/voice). In particular, across facial and vocal modalities sensitivity was higher for anger (compared to happiness and sadness). Also, across facial and vocal modalities response bias was higher to sadness (compared to anger and happiness). These findings suggest that children are more competent at recognising anger from both faces and voices and more likely to attribute sadness to faces and voices when uncertain of the emotion expressed.

Fifth, overall, there was limited evidence for association between psychopathology and emotion processing. The associations found were not specific to a particular emotion and there was some inconsistency across studies regarding modality-specific patterns of associations. Similarly, there was limited evidence for emotion processing biases in children with externalising or internalising psychopathology.

Study 1 showed a negative relationship between vocal emotion recognition accuracy and externalising psychopathology in children. However, these effects were not replicated in Study 3. There are a number of possible reasons for this. For example, Study 1 recruited a sample of children enriched for levels of symptoms from the clinical services whereas Study 3 was based on a community sample of children. Therefore, the level of symptoms in Study 3 was lower compared to Study 1. In addition, Study 3 employed non-linguistic stimuli while Study 1 employed linguistic stimuli. It is therefore possible that children with behaviour problems in Study 1 may have difficulty in emotion processing in combination with language processing. Previous research has shown that language processing can have a distracting effect on children's vocal emotion processing (Morton & Trehub, 2007) and that adults with ADHD were better at processing emotion but worse at processing words in a dichotic listening task compared to controls (Hale, Zaidel, McGough, Phillips & McCracken, 2006). Word processing difficulties may underlie vocal emotion processing difficulties in children with hyperactivity. This further highlights the importance of adopting stimuli devoid of linguistic content in order to isolate emotional prosody perception. Finally, Study 3 examined emotion recognition in a group of 4- to 10-year-old children in contrast to Study 1 recruiting a group of younger children (preschoolers). It is possible that associations between vocal emotion processing and externalising psychopathology are limited to younger ages and that children may outgrow difficulties as they become older and more competent at recognising emotions from vocal expressions.

In addition, in Study 3 there were limited associations between facial emotion processing and child psychopathology, which were not found in Study 1 with preschoolers. For example, emotional problems in children were negatively associated with accuracy to recognise sad facial expressions in Study 3. One possible reason for this discrepancy in the findings between the two studies may be the different age of the children. For example, younger (i.e. preschool) children, with behaviour problems may have greater difficulties in recognising vocal emotional expressions, while older (i.e. school-aged) children may present similar difficulties with facial emotional expressions. In summary, the nature of emotion processing difficulties in children with behaviour problems may change with development (review by Uekermann et al., 2010). Alternatively, children with behaviour problems may have difficulties in processing emotional speech (Study 1) but no difficulties in processing emotional prosody (Study 3).

The main findings of the second, part of the thesis, consisting of an electrophysiological exploration into facial and vocal emotion processing, can be summarised as follows:

First, this research provided evidence for an electrophysiological marker of vocal anger processing in 6- to 11-year-old children from the community. This is a novel finding of the present programme of research. In particular, the N400 was attenuated to vocal anger compared to neutral and happy voices across scalp regions. This is an interesting finding given the lack of ERP studies using emotional prosody stimuli in typically developing school-aged children. In contrast, there was no evidence for ERP markers of anger processing from facial expressions in the same sample of children from the community. This finding is partly consistent with previous developmental ERP research in facial emotion processing in similar age groups. In summary, ERP markers of anger processing were limited to the vocal modality and did not span across modalities (voice/face) in typically developing school-aged children. Laterality effects on ERPs to emotional expressions were generally few and inconsistent, especially in the vocal modality.

Second, there were, overall, few associations between psychopathology and ERP markers of anger processing in children. In particular, emotion dysregulation was negatively associated with the A-N (angry minus neutral) amplitude difference score for the N400. Also, there was a negative relationship between conduct problems and the A-N (angry minus neutral) amplitude difference score for the N400, suggesting that the difference in N400 amplitudes between angry and neutral voice processing tended to become smaller as the level of child symptoms increased. In other words, angry and neutral vocal expressions may be processed similarly by children with conduct problems and emotion dysregulation. In contrast, children with internalising symptoms (anxiety and depression) displayed general, non emotion-specific, difficulties in processing facial expressions, as reflected by a negative relationship between internalising symptoms and Slow Wave (SW) and P300 amplitude to facial expressions. These findings suggest that children with internalising symptoms may possibly present difficulties in attention and visual working memory during face processing. However, there were only non-significant trends for associations between psychopathology and ERPs to facial and vocal expressions and caution should be taken when interpreting the results.

In thinking about the first part of the thesis (behavioural exploration) in light of the second part of the thesis (electrophysiological exploration), a number of observations can be made. These observations demonstrate the utility of combining behavioural and ERP methods in investigating the cognitive processes underlying emotion processing.

First, children not only showed relatively high accuracy to recognise vocal emotional expressions, as demonstrated in the first part of the thesis, but they also displayed differential neural sensitivity to the emotional message of the vocal expressions. This strengthens the conclusion that sensitivity to vocal emotional signals is a fundamental and early developing mechanism, which has a prominent role in prioritizing significant stimuli form the social environment. Findings from the behavioural and ERP studies, taken in combination, suggest that vocal signals provide a more ecological valid and effective tool in assessing the perception of emotion. Current findings may be useful for future research seeking more sensitive methodologies to capture emotion perception in children. On the other hand, it should be acknowledged that ERPs may not have been sensitive enough to pick up the effect of emotion from facial expressions. As discussed in section 5.1.2, the ERP signal is sensitive to only a limited subset of cortical neurons. Neuroimaging techniques (i.e. fMRI) may be more suitable for measuring subcortical responses to facial emotional expressions. It is possible that that the differential sensitivity of ERPs to facial and auditory stimuli rather than the type of stimuli may explain the observed differences in recognising emotion from different modalities.

Second, although neural sensitivity to emotional information from voices is in place in the school-aged years (Study 4), the child brain does not show differential sensitivity to emotional information from faces during this same period (Study 5). Although these results may partly be limited by methodological issues, such as type of stimuli and tasks, and replication is necessary, they seem to suggest that sensitivity to vocal emotion has earlier developmental origins compared to sensitivity to facial emotion. In other words, although at a performance level children were able to recognise facial emotional expressions at high accuracy rates, a neural mechanism responsible for prioritizing facial emotional stimuli may not emerge until later development (i.e. adolescence) (Batty & Taylor, 2006). A developmental advantage of vocal over facial signals is possible given that sensitivity to vocal signals develops before birth (DeCasper & Fifer, 1980) whereas sensitivity to facial signals emerges after birth.

Third, sensitivity to facial and vocal emotional expressions was positively associated in the behavioural studies, suggesting that both modalities are important and equally contribute to social competence during childhood. Unfortunately, it was not possible to investigate this relationship in the ERP studies. The main reason for this was the slightly different sample composition in the two ERP studies after excluding different children with incomplete data and artifacts from each study. Future ERP studies should examine systematically the relationship between neural sensitivity to facial and vocal emotional expressions.

Fourth, findings from the first and second part of the thesis taken in combination provide, overall, limited evidence for associations between emotion processing difficulties and child psychopathology. Associations between vocal emotion processing difficulties and externalising behaviour problems found in Study 1 in preschoolers were only partly supported by electrophysiological evidence in older children. The associations between the N400 and child externalising psychopathology were marginal, and therefore, no conclusive evidence for a vocal emotion-specific deficit can be provided. Similarly, Study 3 showed a negative relationship between emotional problems and accuracy to recognise sad facial expressions; however, it was not possible to examine the emotion-specificity of such difficulties at an electrophysiological level because a clear marker of facial emotion processing was not observed. Nevertheless, it is interesting to note that both behavioural (Study 1) and electrophysiological (Study 4) exploration indicated that difficulties in recognising vocal emotional expressions tended to be present in children with externalising compared to internalising symptoms. In contrast, behavioural (Study 3) and electrophysiological (Study 5) exploration converged to the finding that difficulties in recognising facial expression tended to be present in children with internalising compared to externalising symptoms. This demonstrates the utility of adopting vocal emotional expression stimuli in the study of externalising child psychopathology. However, it should be acknowledged that associations were, overall, did not survive multiple comparison correction.

9.3 Theoretical Implications

Findings of the present research make an important contribution to developmental theories of facial and vocal emotion processing.

First, consistent with existing developmental theory, current findings suggest that by the preschool years sensitivity to emotional messages displayed by facial expressions is well-established (Camras & Allison, 1985; Gosselin, 1995; Philippot & Feldman, 1990; Smiley & Huttenlocher, 1989). In addition, the role of emotion type and intensity are particularly important for the development of sensitivity to facial emotion. Furthermore, although sensitivity to facial emotion is well-established early in development, there is a continuing improvement of recognition accuracy with age. Results build upon developmental models highlighting the preschool years as a landmark in the development of emotion understanding (Widen & Russell, 2008). The preschool years seem to represent the developmental period laying the foundations for later emotional and social competence (Denham et al., 2003; Saarni, 1999). Also, current findings confirm previous developmental perspectives suggesting that an adult-like pattern of facial emotion recognition begins to emerge in pre-adolescence (Batty & Taylor, 2006). Pre-adolescence, therefore, marks a second important developmental transition for the development of recognition of facial emotional expressions. In addition, response bias to facial expressions decreased with development, especially from the preschool years to middle childhood. Current findings on developmental patterns in response bias extend previous developmental theory and research focusing merely on recognition accuracy. It is important that future research takes into account error patterns in children's performance for a more complete measurement of children's sensitivity to emotional expressions. Response bias is an important measure as it reveals the inference processes underlying recognition; whether, for example, children show a systematic tendency to attribute a particular emotion to an expression when uncertain for the correct response.

Second, current findings extend previous knowledge in vocal emotion processing. Adult listeners can reliably recognise different emotions from vocal cues (Laukka, 2004); however, how the processing of emotional prosody develops was poorly understood in the previous literature. A systematic examination of the developmental pattern of emotional prosody processing in 4- to 10-year-olds and adults had not been addressed previously. The present thesis represents the first attempt to study the processing of emotional prosody independently of linguistic content at different intensities in young children of different ages. In this research preschoolers presented reasonably high sensitivity to emotional prosody and emotion effects on accuracy were similar to those previously reported in adults with similar (non-linguistic) stimuli (Maurage et al., 2007). In addition, consistent with the developmental literature in processing emotions from speech, the present thesis supported a developmental progression of the ability to recognise emotions from prosody (Baum & Nowicki, 1998; Hortacsu & Ekinci, 1992; Maxim & Nowicki, 1997; Rothman & Nowicki, 2004). Adult-like patterns of processing emotional prosody seemed to emerge after 10 years of age, whereas adult-like patterns of processing emotional speech have been found to emerge at about 10 years (Baum & Nowicki, 1998). This suggests that although sensitivity to emotional prosody is well-established in the preschool years, it follows a more protracted developmental course compared to processing emotional speech. Finally, this research extended previous knowledge by incorporating response bias as well as accuracy in the study of vocal emotion processing and demonstrating a developmental pattern of response bias to emotional prosody.

Third, a positive relationship between children's sensitivity to facial and vocal emotional expressions was also supported in this research. In addition, emotion-specific patterns of recognition spanned across modalities. The above findings suggest that competence for facial and vocal emotion processing develop in parallel to promote emotional competence in children. This relationship was found at different stages in development (i.e. at 4, 6, 8 and 10 years), suggesting some developmental continuity in successful bimodal emotion processing. A positive relationship was also found between response bias to facial and vocal expressions, suggesting common error patterns and inference processes underlying emotion processing across modalities. Findings build upon previous adult work supporting bidirectional links between emotion processing from visual and auditory channels (Gelder & Vroomen, 2000). It is important that future research incorporates both vocal and facial stimuli for a more accurate and ecological valid measurement of social communication patterns.

Fourth, the present research provided valuable insights into the time course of brain processes engaged in vocal emotion processing. Empirical findings of the thesis advance knowledge on the electrophysiological correlates of emotional prosody perception and provide for the first time evidence for a neural marker of vocal emotion prosody perception in typically developing 6- to 11-year-old children. The N400, in particular, was the strongest index of vocal emotion processing. The N400 was reduced to angry compared to happy and neutral vocal expressions in the present thesis across scalp regions. This component has traditionally been linked to semantic memory use in language comprehension (Kutas & Hillyard, 1980) and emotion processing perception (Schirmer et al., 2002) in healthy adult individuals. The N400 has previously been found to be reduced for angry compared to happy and neutral words (Kanske & Kotz, 2007; Stewart et al., 2010). Previous models have suggested that this reduction of the N400 to anger might reflect a facilitated processing of anger (Kanske & Kotz, 2007). For example, anger may be a warning signal or it may prime defensive systems. However, it is difficult to exclusively interpret the present findings in light of the adult literature using visual (i.e. word) stimuli (Kanske & Kotz, 2007). In summary, the present findings bring an important missing piece to the puzzle of the neural development of emotional prosody processing. Future studies should aim to understand the exact functional significance of these emotion-sensitive components in children's voice processing.

Fifth, the present research provided insights into the time-course of brain processes underlying facial emotion processing. The existing literature in the neural processing of facial emotion has focused in adult individuals and few studies had addressed the above issue in developmental populations. Current findings supported the notion that neural sensitivity to facial emotion is not present in the developmental period between 6-11 years in typically developing children. Findings seem to be compatible with developmental models suggesting that neural sensitivity to facial emotion, at least as reflected by the 'face-specific' N170, does not emerge until later in development, (i.e. pre-adolescence) (Batty & Taylor, 2006). This suggestion is consistent with previous behavioural work (Tonks et al., 2007). However, the ability to compare the results with those of previous research is limited by different methodological paradigms and stimuli adopted by the current and previous research and lack of an adolescent group in the current research. There is generally little consensus in the literature on the influence of facial emotion on ERPs. Alternative theoretical models, for example, have argued that facial emotion does not modulate the ERPs in healthy adult individuals (Eimer et al., 2003). It is therefore, difficult to establish a truly mature 'endpoint' in the development of neural sensitivity to facial emotion.

Finally, findings of the present thesis make an original contribution to research at the intersection of three separate, but closely related areas; voice processing, child externalising psychopathology and social neuroscience. To the best of the present author's knowledge these inter-connections have not been previously addressed in the literature. Due to the diverse findings reported previously, and the lack of electrophysiological evidence to supplement behavioural research, no unified theory of emotion processing in child psychopathology has yet been proposed in the field of cognitive developmental neuroscience. The present work, although not providing definite answers, represents a springboard for future discussion and new ideas on this important topic.

In particular, the present thesis aimed to clarify modality-specific (facial/vocal) emotion processing difficulties in children from the community with a range of behaviour problems, including hyperactivity, conduct problems and emotional problems. Further, the thesis allowed the disaggregation of the possible emotion processing mechanisms via use of ERP methodology, thus revealing cognitive processes which would not otherwise be directly observable in children's behavioural performance (Herba & Phillips, 2004). This research adopted a special focus on anger processing at an ERP level because this was the emotion highlighted by previous ERP research in child psychopathology.

Existing theory and empirical research have suggested that poor social skills in children with behaviour problems may stem from inaccurate understanding of others' emotions (Pelc et al., 2006) or a biased perception of emotional expressions (Cadesky et al., 2000). Previous literature had highlighted links between child externalising and internalising behaviour problems and emotion processing difficulties; although the mechanisms underlying this relationship were unclear. It was unknown whether such deficits in emotion processing were due to an actual emotion (i.e. anger) processing style. It could be argued that hyperactive children fail to attend more generally to visual and auditory stimuli, independent of emotional valence, and therefore these deficits are not specific to emotion and are instead a function of inattention or impulsivity. Cognitive-behavioural theoretical models (Barkley, 1997b) have argued in favour of a ‘general cognitive ability’ account of emotion processing difficulties in children with behaviour problems, such as hyperactivity. Alternative theoretical approaches have emphasised motivational aspects of child behaviour and the different value that children attribute to different behavioural outcomes (Sonuga-Barke, 2002; Sonuga-Barke et al., 1992).

Conclusions from the present thesis on the above theoretical debate are not definitive. Overall, the thesis provided limited evidence on emotion-specific difficulties in children with behaviour problems. It is possible that other factors, such as inattention, impulsivity or general difficulties in non-emotional auditory and visual processing, may contribute to emotion processing difficulties in children with behaviour problems. Future research should systematically address this hypothesis by incorporating, for example, an attention control task alongside an emotion recognition task. An alternative interpretation of the present findings may be that emotion processing difficulties may exacerbate already existing problems in attention or impulsivity, suggesting a reciprocal influence of attention and emotion-specific difficulties on child psychopathology.

Similarly, the thesis provided limited ERP evidence for anger-specific difficulties. Electrophysiological analysis of potential difficulties uncovered a tendency for symptoms of conduct problems and emotion dysregulation to be negatively associated with an A-N (angry minus neutral) N400 difference amplitude score. One possible interpretation for this finding could be that the N400 difference amplitude score between angry and neutral voices became smaller as the level of symptoms increased. How children perceive vocal anger and differentiate between angry and non-angry (i.e. neutral) signals may be closely related to ways children express anger, frustration and oppositional behaviour. Also, it is likely that these processes are closely related to general emotion dysregulation in children (Eisenberg et al., 2001). However, alternative interpretations of this finding are also possible. With regard to the time-course of vocal anger processing, it should be noted that these tendencies were observed at a rather late stage of information processing (N400).

In regards to the role of comorbidity, although general evidence for emotion-specific difficulties was limited, when associations or tendencies with child symptoms were observed, these were related more strongly to conduct problems compared to hyperactivity. Conduct problems might be a dissociable condition from hyperactivity (Jensen et al., 2001; Smalley et al., 2000). Conduct problems are characterised by higher levels of emotional lability (Sobanski et al., 2010) and emotion dysregulation (Frick & Morris, 2004) and more pronounced difficulties in social skills (Hampel et al., 2008), although emotional reactivity is also high in children with ADHD (Jensen & Rosen, 2004). Finally, there was limited evidence in the present thesis for emotion processing biases in children with anxiety and children with conduct problems. This finding does not support previous models suggesting information processing biases in children with anxiety (review by Hadwin & Field, 2010; Waters, Lipp, & Cobham, 2000; Waters & Valvoi, 2009) and children with conduct problems (Dodge, Bates, et al., 1990). It should be acknowledged, however, that the levels of anxiety in the children included in the present thesis were low. Research in the present thesis provided initial evidence for general difficulties in processing facial expressions across emotions in children with anxiety and depression, an effect which was not present in children with externalising symptoms. Although these associations were not strong, general face processing difficulties in children with internalising psychopathology are consistent with previous work in childhood anxiety suggestive of decreased ability to discriminate facial expressions (Richards et al., 2007) and lower recognition accuracy for neutral facial expressions (Leist & Dadds, 2009).

9.3.1 The Possible Role of Parent Characteristics in Children's Emotion Processing

Grounded on theoretical models of developmental psychopathology (Cicchetti & Rogosch, 2002), proposing that patterns of adjustment during development emerge from interactions between child characteristics and the social environment, the thesis provided a behavioural and electrophysiological exploration of the role of parental psychopathology (symptoms of ADHD and depression) and sense of parenting competence in children's emotion processing.

The thesis revealed reduced facial and vocal emotion recognition accuracy in preschool children of parents with ADHD and depressive symptoms (Study 1). In contrast, parents who felt more competent in their parenting role had children who were more accurate in understanding emotional expressions. Although these findings suggest that emotion processing may be compromised in atypical parenting environments (Norvilitis et al., 2000) and fostered under conditions of greater parental well-being and sense of competence, these effects did not hold after controlling for child psychopathology. This suggests that both parent and child characteristics need to be taken into account in future investigations. It should also be noted that associations between parent characteristics and children's emotion processing did not hold when applying Bonferooni corrections.

Similarly, parent hyperactivity was positively associated with children's central P2 and P3 amplitudes to angry vocal expressions, possibly suggesting amplified attention to threatening (i.e. angry) signals in children of parents with externalising symptoms. In addition, symptoms of parent depression were negatively associated with children's N400 amplitude to angry vocal expressions. However, no significant associations emerged between parental psychopathology and the A-N (angry minus neutral) amplitude difference score for any ERP component. This suggests that the above associations may not be anger-specific.

In summary, the present thesis offered a first exploratory investigation on this topic. It should be acknowledged that conclusions regarding the role of parent characteristics in children's emotion processing are constrained by some limitations. It is important to highlight the ambiguous nature of the processes underlying the integerational transmission of emotion processing deficits in the current research. A number of mechanisms for risk transmission from parents to children have been proposed (Ramchandani & Psychogiou, 2009). From the present findings it is not possible to conclude whether children's poor recognition of emotional expressions is related to changes in parental behaviour associated with parental psychopathology (depression or ADHD symptoms) or rather a genetic predisposition to display emotion-specific deficits. For example, in a recent study, atypical neural responses to affective prosody (i.e. shorter MMN to affective sounds) were observed not only in children with Aspergers Syndrome (AS) but also in their fathers when compared to controls (Korpilahti et al., 2007). These findings would suggest familial patterns of abnormal brain responses to vocal emotional stimuli. From the research conducted in the context of present thesis it cannot be concluded whether children develop emotion processing deficits through genetic endowment (i.e. risk genes) or the influence of parental psychopathology on the environment. Future studies should address this important issue by employing a family design.

9.5 Clinical Implications

Evidence in the present thesis linking poor emotion understanding to child behaviour problems was limited. Therefore, until findings of the present thesis are replicated in clinical samples of children clinical implications of the current research are limited.

Recent research (Izard et al., 2008) has emphasised the need for emotion-centred intervention and prevention efforts, highlighting the adaptive functions of emotions and acknowledging that poor emotion understanding may place children on a trajectory to psychopathology. Within this framework, intervening early can help children 'read' emotions in others successfully, develop social skills and reduce problem behaviours. Social skills training has the potential to develop into a useful treatment approach for children with externalising behaviour problems (Nangle, Erdley, Carpenter, & Newman, 2002). Some of these efforts have been effective in reducing externalising problems in children (Webster-Stratton, Jamila Reid, & Stoolmiller, 2008; Webster-Stratton, Reid, & Hammond, 2001). Emotion-centred preventive intervention programs for children at risk for conduct problems have incorporated in their curricula emotion recognition lessons (Conduct Problems Prevention Research Group, 1992).

Data from the present programme of research, however, do not support changes to clinical practice. Similarly, in light of the large between-subject variability of ERPs (see section 5.1.3) ERPs cannot currently be used for clinical purposes. Although differences may be observed on a group level (e.g., schizophrenics vs. healthy controls), the technique is not sensitive or specific enough to determine which group a person falls into on the basis of the ERP recording. Grand-average ERPs lack important information which is only available at a single-subject level. Clinical groups are often heterogeneous and small in size. Therefore, the use of grand-averages based on a large number of individuals may produce misleading results. One should carefully consider the variability of ERPs in terms of latency and amplitude in clinical groups and average ERPs across patients with caution. It is recommended that in cases in which ERPs from clinical patients are averaged, representative ERPs from single-subjects should be examined, for example, by presenting individual data in patient groups and control participants in scatter graph or histograph (Picton et al., 2000).

9.6 Limitations

Although the present research has overcome several limitations of previous research, a number of limitations are acknowledged.

First, the current research was based on a sample of children from the community with varying levels of internalising and externalising symptoms. This decision was made in order to increase the power in the sample. However, the low levels of symptoms in children from the general population, when combined with high levels in performance, may not have allowed clear associations between child psychopathology and emotion processing difficulties to emerge. For this reason, conclusions in the current thesis should be treated with caution until replicated in a clinical sample of children. Also, as the focus of the present programme of research was on externalising behaviour problems, the current research recruited an enriched sample of children with externalising symptoms, which may have influenced the representation of internalising symptoms in the sample.

Second, aspects of the present research related to the choice of the experimental task design might have influenced the results, especially in Study 5. The present research has adopted an explicit emotion recognition task requiring attention-dependent processing of emotional expressions. This task design was adopted across studies of the thesis for consistency in the interpretation of the findings. Previous research has shown that processing of facial emotional expressions may occur rapidly and involuntarily (Vuilleumier & Pourtois, 2007), although, there is still considerable controversy as to whether emotional expressions are processed outside conscious awareness (Pessoa & Adolphs, 2010). It is possible that an implicit emotion recognition task may have allowed sensitivity of brain activity (ERPs) to facial emotional expressions to emerge in children.

Along similar lines, the present research relied on cognitive components (ERPs) as markers of attention allocation to stimuli (i.e. P3). However, it would be useful to supplement the emotion recognition task with an attention control task. This would provide a more direct measure of attentional allocation to stimuli against which to determine the emotion-specificity of observed deficits in children with inattentive/hyperactive symptoms. Additional data collection in this thesis was limited by the amount of testing time required for each child.

Third, the properties of the stimuli used in the present programme of research, although well-defined and validated, may have limited the results in the current thesis. For example, in this research facial and vocal stimuli were presented in isolation. However, in real-life situations facial and vocal messages are displayed in combination and facial expressions are dynamic (in motion) rather than static. The stimuli adopted could therefore, be improved in terms of their ecological validity. Similarly, because the aim of the ERP studies in this thesis was to maximise the number of correct and artifact-free trials, emotional expression stimuli were presented at the highest level of intensity (100%). These stimuli may have lacked ecological validity, as real-life expressions are presented at different intensity levels. Also, in previous work children with behaviour problems had difficulties in recognising only the low (but not high) intensity in the vocal expression (Baum & Nowicki, 1998).

In regards to the vocal stimuli adopted, it is equally important for future research to incorporate additional control sound categories as well as vocal expressions. This will help further clarify whether the effects observed in this research reflected vocal anger processing or the acoustical differences between the sound categories (e.g. f0 range). The present research demonstrated 'sensitivity' of ERPs to vocal anger. However, the issue of 'selectivity', referring to selective responding to vocal anger compared to control sounds (Belin & Grosbras, 2010) remains to be addressed by future research.

In respect to the cross-sectional design adopted throughout the present thesis, caution should be taken when interpreting the results. Cross-sectional designs do not permit researchers to determine the temporal order of events. Therefore, in the context of the present thesis, it was not possible to establish whether difficulties in children's emotion processing may contribute to behaviour problems or, instead, whether it was the behaviour difficulties in children which contributed to deficits in emotion processing. Findings of the present research were constrained by a correlational design and no conclusions on causal relationships can be drawn. Longitudinal studies should aim to address this limitation in the future. Similar considerations apply to the design of the developmental study of the present thesis. Developmental studies following a longitudinal design would permit more robust conclusions in terms of the developmental stages of facial and vocal emotion recognition in children and would represent a fruitful area for future research.

In relation to the ERP analyses, one should acknowledge the strengths and limitations of alternative ERP analysis methods. In line with previous developmental literature, the current research adopted a baseline-to-peak mean amplitude method to examine the vocal and facial emotion modulation of ERPs. This decision was taken in the absence of clear and consistent peaks in the ERP data (Fabiani et al., 2007). An alternative way of quantifying ERP components in the current research would be to adopt a peak-to-peak amplitude method. This method presents a number of advantages over the baseline-to-peak amplitude method (see section 5.1.4). In addition, frequency analysis, such as wavelet analysis, would help to clarify the pattern of low frequency oscillation on which the N400 to emotional vocal expressions was superimposed in Study 4. Oscillatory processes of neural ensembles can be very useful in understanding the mechanisms underlying sensory and cognitive functions in the human brain (Basar, 1998; Basar et al., 1999). For example, slow potentials in ERPs as represented by theta or delta activity have been associated with signal detection and decision making (Basar et al., 1999), valence of affective pictures (Klados et al., 2009) and processing of emotional compared to neutral facial expressions (Balconi & Pozzoli, 2007) in healthy adult individuals. In summary, oscillatory analysis would represent a useful way to supplement the ERP analyses presented in the present thesis.

In addition, the present thesis explored the role of parent characteristics in children's emotion processing; however, the exploratory nature of this investigation should be emphasized. As discussed above, conclusions from the present research are limited by the absence of a genetic design that would help clarify the genetic versus environmental influence of parental psychopathology on children's emotion processing.

A further limitation includes the lack of a hypothesis-driven approach to the study of emotion processing. The present research consisted of an exploration of many different issues, including the typical development of facial and vocal emotion processing, the effect of child and parent psychopathology on children's emotion processing and laterality effects on ERPs. The statistical limitations of this approach should be recognised. Because the current research followed an exploratory approach with no specific predictions, correlations had to be submitted to Bonferroni corrections for multiple comparisons to avoid a Type I error. Therefore, few of the results remained significant after controlling for multiple testing. A more focused approach with a priori testable predictions would have allowed the research to reveal potential significant differences that could not be detected with the current exploratory design.

9.7 Directions for Future Research

Despite the limitations of the research presented herein, the present research can provide a fruitful avenue for future research. A number of different directions can be considered as an extension of the findings from the current research. Some of these are discussed below.

First, as noted above because the present study was based on a community sample of children with varying levels of symptoms, future studies should include clinical populations. Future research should aim to reproduce current findings with a clinical sample of children with behaviour problems, such as conduct problems and emotion dysregulation. This would help to clarify whether emotion processing difficulties are a reliable correlate of child behaviour or whether, instead, the effects observed in the current research were rather due to methodological aspects of the research, such as child age, task design and stimuli features. It would be equally important for future research to include a clinical group of children with hyperactivity and internalising symptoms. This would allow more conclusive evidence on the nature of emotion processing profiles in children with different psychopathological conditions. Following replication of emotion difficulties in a clinical group, longitudinal studies should examine the causal relationship of such difficulties to the development of conduct problems.

It should be acknowledged that the present research (Study 4) used a formal assessment of hearing ability in children alongside the assessment of vocal anger processing; however, this was used only at a behavioural level. It would be worthwhile for future ERP studies in clinical groups of children to incorporate an auditory processing task of control sounds alongside emotion identification tasks. This would enable researchers to conclude with greater certainty that children's brain activity patterns were specific to vocal anger rather than general auditory processing and stimulus features.

In addition, future studies should aim to increase the ecological validity of the stimuli. One way to achieve this would be to employ a cross-modal design, which would allow the presentation of facial and vocal emotional expressions in combination, as is the case of real-life social situations. Also, stimuli which are dynamic (i.e. animated), colourful and displayed at different intensity levels (i.e. 50%, 75% etc.) would be more likely to capture emotional expressions as they unfold in real-life settings. Morphed facial and vocal expression continua spanning across a number of expression pairs (anger-happiness) or stimuli morphed from neutral to emotional (neutral-anger) across different ratios would provide an alternative measurement of emotion perception (Calder et al., 1996). In addition, in real-life settings, faces and voices often display incongruous emotional messages (i.e. angry voice - neutral face), however, the influence of this incongruity on children's accuracy and bias has not been examined systematically so far and would represent a useful direction for future research.

An alternative avenue for future research would be to examine in more detail the socialisation influences on children's emotion processing. One way to address this issue would be to examine the effect of children's familiarity with the expresser (i.e. mother-stranger) or children's familiarity with a particular emotion (i.e. anger) on brain activity patterns. This would clarify whether familiarity and the meaning that children attach to emotional stimuli can impinge on children's perceptual and cognitive processing. Previous work has shown, for example, that physically abused children identified their mothers' vocal anger more frequently than that of a stranger (Shackman & Pollak, 2005) and had difficulties disengaging attention from angry faces (Pollak & Tolley-Schell, 2003). Future ERP studies could examine whether children with behaviour problems would present differential neural sensitivity to their mothers' vocal anger compared to that of a stranger.

Finally, future ERP research in facial emotion processing should consider employing alternative experimental paradigms. For instance, ERP studies using implicit emotion processing tasks, requiring the identification of targets (i.e. objects) among non-targets (facial emotional expressions), would be a potential candidate direction for future research. Implicit emotion processing tasks could possibly capture sensitivity of ERPs to emotional information from facial expressions more efficiently compared to explicit emotion processing paradigms. Implicit tasks would clarify whether the observed lack of facial emotion modulation of the ERPs observed in this research relates to task differences (i.e. attention dependent versus subliminal processing of emotion) or a developmental pattern of facial emotion processing that views the neural sensitivity to emotion emerging in later developmental periods (i.e. pre-adolescence).

9.8 Conclusion

It has been proposed that children with behaviour problems present difficulties in understanding others' emotions from facial expressions and tone of voice (Pelc et al., 2006; Shapiro, 1993) and that this may account for the difficulty in these children to relate socially to others. However, this suggestion has not been empirically tested with school-aged children at both a behavioural and electrophysiological level using vocal and facial stimuli. The present research has explored emotion processing difficulties in children with behaviour problems. In addition, the present research aimed to uncover the underlying cognitive components of potential difficulties via use of ERP methods. The present thesis provided useful normative developmental information on the recognition of facial and vocal emotional expressions in children. Evidence on the relationship between emotion-specific difficulties and child psychopathology from the present research is not conclusive. This research provided initial ERP evidence for general face processing difficulties in children with internalising symptoms. An original contribution of this thesis was to identify a neural marker of vocal anger processing and provide initial evidence for associations with child behaviour. The identification of a neural marker of vocal anger processing in children opens up a spectrum of opportunities for future research.

APPENDICES

APPENDIX A-Study 1

Table A. 1 *Percent agreement on how representative each vocal item was of each emotion*

		Raters' Classification			
Item No	Vocal Expression	Angry	Happy	Sad	Neutral
1	Angry-75	94.4	0	0	5.6
2	**Angry-50**	**88.9**	**0**	**0**	**11.1**
3	Happy-75	5.6	0	44.4	50.0
4	Happy-50	0	5.6	27.8	66.7
5	Sad-50	0	0	94.4	5.6
6	**Sad-75**	**0**	**0**	**77.8**	**22.2**
7	Neutral	5.6	5.6	16.7	72.2
8	Angry-75	50.0	16.7	5.6	27.8
9	Angry-50	22.2	5.6	0	72.2
10	Happy-75	0	77.8	5.6	16.7
11	Happy-50	0	5.6	38.9	55.6
12	Sad-75	0	0	100.0	0
13	Sad-50	0	0	100.0	0
14	Neutral	11.1	5.6	16.7	66.7
15	Angry-75	100.0	0	0	0
16	Angry-50	50.0	5.6	0	44.4
17	Happy-75	0	88.9	0	11.1
18	Happy-50	0	55.6	11.1	33.3
19	Sad -75	0	0	88.9	11.1
20	Sad-50	5.6	0	83.3	11.1
21	Neutral	22.2	5.6	11.1	61.1
22	Angry-75	88.9	5.6	5.6	0
23	Angry-50	11.1	0	38.9	50
24	Happy-75	0	88.9	0	11.1
25	**Happy-50**	**0**	**83.3**	**5.6**	**11.1**
26	Sad-75	5.6	0	88.9	5.6
27	Sad-50	0	5.6	83.3	11.1
28	Neutral	11.1	0	16.7	72.2
29	Angry-75	94.4	5.6	0	0
30	Angry50	22.2	5.6	5.6	66.7
31	Happy-75	11.1	83.3	0	5.6
32	Happy-50	0	77.8	5.6	16.7
33	**Sad-75**	**0**	**0**	**94.4**	**5.6**
34	Sad-50	0	0	94.4	5.6
35	Neutral	11.1	11.1	0	77.8
36	**Angry-75**	**94.4**	**0**	**5.6**	**0**
37	Angry-50	0	0	16.7	83.3
38	**Happy-75**	**0**	**100.0**	**0**	**0**
39	Happy-50	0	66.7	5.6	27.8
40	Sad-75	0	0	100.0	0
41	Sad-50	0	0	100.0	0
42	Neutral	5.6	16.7	5.6	72.2
43	Neutral	0	27.8	0	72.2
44	Neutral	0	11.1	22.2	66.7
45	**Neutral**	**0**	**5.6**	**0**	**94.4**
46	Neutral	0	11.1	11.1	77.8

Note: 50 -low intensity, 75 -high intensity. In bold the final 7 items included in Study 1.

Table A. 2. *Number of items classified as 'Neutral' and their mean (SD) intensity rating in adults (N=18)*

Item No	Vocal Expression	Mean	SD
45	Neutral	**4.88**	**2.13**
43	Neutral	4.38	3.03
42	Neutral	4.27	3.02
46	Neutral	4.27	2.76
35	Neutral	4.00	2.54
37	Angry-50	3.94	2.26
44	Neutral	3.83	3.07
7	Neutral	3.72	2.71
14	Neutral	3.66	3.02
28	Neutral	3.44	2.38
30	Angry-50	3.27	2.71
9	Angry-50	3.16	2.35
4	Happy-75	2.94	2.64
11	Happy-50	2.94	3.07
23	Angry-50	2.55	2.83
21	Neutral	2.44	2.28
16	Angry-50	2.33	2.93
3	Happy-50	2.05	2.33

Note 1: In bold the neutral item selected for Study 1. Note 2: 1-8 rating scale.

Table A. 3. *Number of items classified as 'Happy' and their mean (SD) intensity rating in adults (N=18)*

Item No	Vocal Expression	Mean	SD
38	Happy-75	**5.72**	**1.74**
24	Happy-75	5.33	2.27
31	Happy-75	4.55	2.79
10	Happy-75	4.33	2.74
17	Happy-75	3.83	2.09
25	Happy-50	**3.77**	**2.36**
32	Happy-50	3.11	2.37
39	Happy-50	2.55	2.40
18	Happy-50	2.00	2.19

Note1: In bold items with approx. 2 units of difference selected for Study 1 to represent 50% and 75% intensity.
Note 2: 1-8 rating scale.

Table A. 4 *Number of items classified as 'Sad' and their mean (SD) intensity rating in adults (N=18)*

Item No	Vocal Expression	Mean	SD
12	Sad-75	7.22	1.35
40	Sad-75	6.83	.78
33	Sad-75	**6.33**	**1.78**
5	Sad-50	6.27	1.84
19	Sad-75	6.11	2.74
26	Sad-75	5.77	2.64
13	Sad-50	5.22	2.07
41	Sad-50	5.11	1.64
34	Sad-50	5.05	1.98
6	Sad-75	**4.11**	**2.58**
20	Sad-50	3.88	2.51
27	Sad-50	3.77	2.28

Note 1: In bold items with approx. 2 units of difference selected for Study 1 to represent 50% and 75% intensity.
Note 2: 1-8 rating scale.

Table A. 5. *Number of items classified as 'Angry' and their mean (SD) intensity rating in adults (N=18)*

Item No	Vocal Expression	Mean	SD
15	Angry-75	7.38	.69
29	Angry-75	7.33	1.87
36	Angry-75	**6.38**	**2.00**
22	Angry-75	5.27	2.53
1	Angry-75	4.55	1.82
2	Angry-50	**4.55**	**2.28**
8	Angry-75	1.77	2.12

Note 1: In bold items with approx. 2 units of difference selected for Study 1 to represent 50% and 75% intensity.
Note 2: 1-8 rating scale.

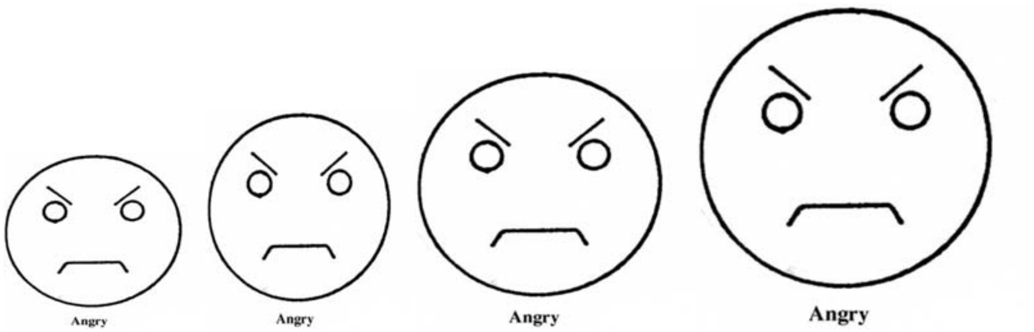
Table A. 6. *Partial Pearson's correlations (p value) between child symptoms and accuracy prior to combining the two intensity levels controlling for child age*

	Child Psychopathology		
Accuracy	Hyperactivity	Conduct problems	Emotional problems
Face			
Angry 50%	**-.27(.044)**	-.09(.526)	-.10(.448)
Angry 75%	**-.32(.017)**	-.21(.117)	-.17(.207)
Happy 50%	**-.28(.035)**	-.20(.146)	-.13(.350)
Happy 75%	-.22(.097)	-.16(.228)	-.22(.098)
Sad 50%	-.16(.238)	-.16(.223)	-.17(.210)
Sad 75%	-.23(.088)	-.20(.125)	-.15(.260)
Voice			
Angry 50%	**-.41(.002)**	**-.28(.036)**	-.12(.382)
Angry 75%	**-.36(.006)**	**-.29(.029)**	-.15(.268)
Happy 50%	**-.29(.029)**	**-.26(.058)**	-.02(.878)
Happy 75%	**-.26(.044)**	**-.28(.040)**	.02(.879)
Sad 50%	**-.44(.001)**	**-.39(.003)**	-.11(.404)
Sad 75%	**-.33(.014)**	**-.30(.024)**	-.03(.831)

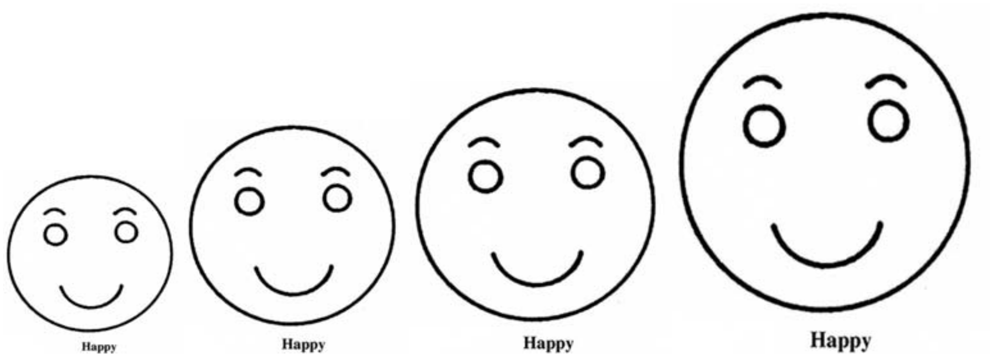
Table A. 7. *Full Pearson's correlations (p value) between child symptoms and response bias*

	Child Psychopathology		
Bias	Hyperactivity	Conduct problems	Emotional problems
Face			
Angry	-.15(.263)	-.07(.587)	-.02(.872)
Happy	-.07(.618)	-.00(.992)	-.12(.371)
Sad	.05(.719)	-.04(.741)	-.01(.934)
Voice			
Angry	-.13(.321)	-.00(.990)	-.03(.820)
Happy	-.07(.618)	-.04(.758)	-.22(.102)
Sad	-.03(.800)	-.04(.764)	.23(.089)

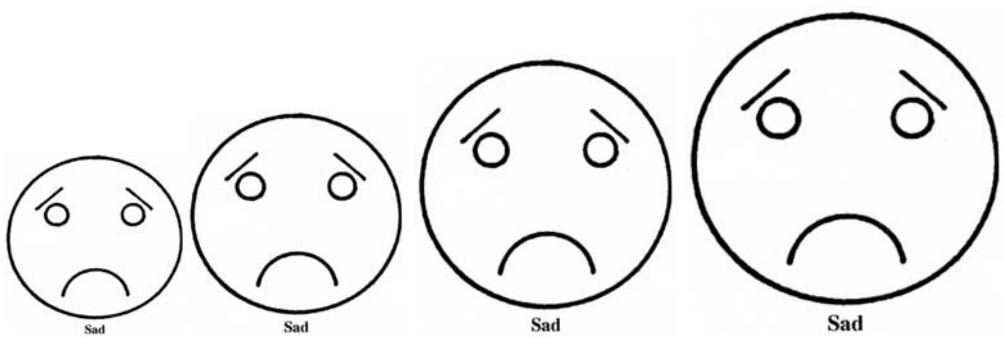
APPENDIX B -Studies 2 and 3



1 2 3 4



1 2 3 4



1 2 3 4

Figure B. 1. Vocal Emotion Rating Task for Children (Chronaki, 2009, Unpublished). Face drawings adapted from Voyer, Bowes & Soraggi, 2009. Figure used with permission.

Table B. 1 *Item by item % agreement on vocal expressions in adults, children and overall sample*

Item No	*Expression*	Angry			Happy			Sad			Neutral		
		Adult	Child	Total	Adult	Child	Total	Adult	Child	Total	Adult	Child	Total
1	**Neutral**	0	11.1	5.0	0	27.8	12.5	22.7	22.2	22.5	**77.3**	**38.9**	**60.0**
2	Happy75%	9.1	22.2	15.0	40.9	27.8	35.0	40.9	38.9	40.0	9.1	11.1	10.0
3	Angry50%	50.0	27.8	40.0	4.5	22.2	12.5	36.4	44.4	40.0	9.1	5.6	7.5
4	**Sad75%**	0.0	11.1	5.0	0.0	5.6	2.5	**86.4**	**55.6**	**72.5**	13.6	27.8	20.0
5	**Happy50%**	40.9	27.8	35.0	**40.9**	**38.9**	**40.0**	9.1	27.8	17.5	9.1	5.6	7.5
6	Angry50%	95.5	61.1	80.0	0.0	5.6	2.5	0.0	33.3	15.0	4.5	0.0	2.5
7	**Happy75%**	4.5	11.1	7.5	**81.8**	**61.1**	**72.5**	13.6	11.1	12.5	0.0	16.7	7.5
8	Neutral	0.0	11.1	5.0	9.1	5.6	7.5	22.7	61.1	40.0	68.2	22.2	47.5
9	Sad75%	13.6	22.2	17.5	4.5	5.6	5.0	22.7	44.4	32.5	59.1	27.8	45.0
10	Happy50%	27.3	27.8	27.5	45.5	27.8	37.5	18.2	33.3	25.0	9.1	11.1	10.0
11	Happy75%	36.4	11.1	25.0	45.5	61.1	52.5	9.1	27.8	17.5	9.1	0.0	5.0
12	**Angry50%**	**40.9**	**38.9**	**40.0**	0.0	11.1	5.0	36.4	44.4	40.0	22.7	5.6	85.0
13	Neutral	9.1	16.7	12.5	9.1	33.3	20.0	13.6	27.8	20.0	68.2	22.2	47.5
14	Sad75%	13.6	11.1	12.5	0.0	16.7	7.5	81.8	55.6	70.0	4.5	16.7	10.0
15	Angry50%	54.5	50.0	52.5	0.0	16.7	7.5	36.4	27.8	32.5	9.1	5.6	7.5
16	Sad50%	4.5	11.1	7.5	9.1	27.8	17.5	0.0	33.3	15.0	77.3	22.2	52.5
17	Sad75%	9.1	16.7	12.5	0.0	27.8	12.5	86.4	33.3	62.5	0.0	11.1	5.0
18	Neutral	4.5	11.1	7.5	13.6	11.1	12.5	36.4	38.9	37.5	45.5	38.9	42.5
19	Angry75%	72.7	11.1	45.0	13.6	44.4	27.5	9.1	27.8	17.5	4.5	16.7	10.0
20	Sad50%	13.6	16.7	15.0	4.5	22.2	12.5	31.8	55.6	42.5	50.0	5.6	30.0
21	Happy50%	27.3	16.7	22.5	68.2	50.0	60.0	4.5	22.2	12.5	0.0	11.1	5.0
22	Angry75%	86.4	33.3	62.5	4.5	33.3	17.5	9.1	22.2	15.0	0.0	11.1	5.0
23	**Angry75%**	**86.4**	**66.7**	**77.5**	13.6	16.7	15.0	0.0	11.1	5.0	0.0	0.0	0.0
24	Happy75%	31.8	33.3	32.5	50.0	44.4	47.5	18.2	16.7	17.5	0.0	5.6	2.5
25	Angry75%	81.8	44.4	65.0	0.0	0.0	0.0	9.1	33.3	20.0	9.1	22.2	15.0
26	Sad50%	4.5	5.6	5.0	9.1	11.1	10.0	59.1	72.2	65.0	22.7	11.1	17.5
27	Happy50%	4.5	16.7	10	13.6	27.8	20	0.0	50.0	45	36.4	5.6	22.5
28	Sad75%	9.1	22.2	15.0	0.0	27.8	12.5	31.8	33.3	32.5	59.1	16.7	40.0
29	**Sad50%**	4.5	27.8	15.0	4.5	22.2	12.5	**45.5**	**33.3**	**40.0**	45.5	16.7	32.5
30	Angry75%	95.5	88.9	92.5	0.0	11.1	5.0	0.0	0.0	0.00	4.5	0.0	2.5
31	Neutral	4.5	22.2	12.5	18.2	22.2	20.0	13.6	38.9	25.0	63.6	16.7	42.5
32	Angry50%	59.1	33.3	47.5	22.7	44.4	32.5	9.1	11.1	10.0	9.1	11.1	10.0
33	Happy50%	22.7	16.7	20.0	50.0	50.0	50.0	27.3	22.2	25.0	0.0	11.1	5.0
34	Happy75%	4.5	33.3	17.5	68.2	16.7	45.0	9.1	33.3	20.0	18.2	16.7	17.5
35	Sad50%	0.0	11.1	5.0	9.1	50.0	27.5	68.2	27.8	50.0	22.7	11.1	17.5

Participants' Response (spanning Angry, Happy, Sad, Neutral)

Note: In bold the vocal items selected for inclusion in Study 3.

Table B. 2. *Number of items classified as 'neutral' and their mean (SD) intensity rating in adults (N=22)*

Item No	Vocal Expression	Mean	SD
Item 1	**Neutral**	**1.05**	**.93**
Item 16	Sad 50%	.85	.89
Item 8	Neutral	.80	.91
Item13	Neutral	.75	.86
Item 9	Sad 75%	.75	.89
Item 28	Sad 75%	.72	.93
Item 18	Neutral	.70	.88
Item 31	Neutral	.70	.88

Note 1: Study 2 selected one item of each emotion and intensity category to use in Study 3 (in bold).
Note 2: 1-4 point intensity scale.

Table B. 3. *Number of items classified as 'angry' and their mean (SD) intensity rating in adults and children (N=40)*

Item No	Vocal Expression	Mean	SD
Item 30	Angry 75%	1.77	.57
Item 6	Angry 50%	1.45	.81
Item 23	**Angry 75%**	**1.42**	**.84**
Item 25	Angry 75%	1.02	.86
Item 22	Angry 75%	1.00	.87
Item15	Angry 50%	.72	.78
Item 19	Angry 75%	.70	.85
Item 32	Angry 50%	.70	.82
Item 3	Angry 50%	.67	.88
Item 12	**Angry 50%**	**.57**	**.78**

Note 1: In bold the items selected for Study 3. Note 2: 1-4 point intensity scale.

Table B. 4. *Number of items classified as 'happy' and their mean (SD) intensity rating in adults and children (N=40)*

Item No	Vocal Expression	Mean	SD
Item 7	**Happy 75%**	**1.22**	**.86**
Item 21	Happy 50%	1.02	.91
Item 11	Happy 75%	.92	.94
Item 24	Happy 75%	.80	.91
Item 33	Happy 50%	.77	.86
Item 34	Happy 75%	.75	.89
Item 10	Happy 50%	.62	.86
Item 5	**Happy 50%**	**.60**	**.81**

Note 1: In bold the items selected for Study 3.Note 2: 1-4 point intensity scale.

Table B. 5. *Number of items classified as 'sad' and their mean (SD) intensity rating in adults and children (N=40)*

Item No	Vocal Expression	Mean	SD
Item 4	**Sad 75%**	**1.02**	**.76**
Item 17	Sad 75%	1.02	.89
Item 14	Sad 75%	1.00	.78
Item 35	Sad 50%	.82	.90
Item 26	Sad 50%	.80	.68
Item 27	Happy 50%	.60	.74
Item 2	Happy 75%	.60	.81
Item 20	Sad 50%	.62	.80
Item 29	**Sad 50%**	**.62**	**.83**

Note 1: In bold the items selected for Study 3. Note 2: 1-4 point intensity scale.

Table B. 6 *Mean percentage (SD) of facial expressions classified correctly (in bold) and misclassifications per emotion and intensity in preschoolers.*

Facial Expression	Preschoolers' response			
	Angry	Happy	Sad	Neutral/ok
Angry 50%	**48.55(.31.84)**	13.40(12.74)	18.11(18.91)	15.94(13.27)
Angry 75%	**60.14(31.67)**	9.78(12.72)	14.12(20.01)	11.23(14.78)
Angry 100%	**71.01(32.26)**	4.34(12.27)	13.76(17.87)	9.05(18.10)
Happy 50%	6.15(9.47)	**63.40(24.19)**	10.86(10.78)	14.85(13.04)
Happy 75%	6.52(12.29)	**75.72(25.85)**	9.05(14.14)	6.88(9.61)
Happy 100%	3.26(6.52)	**77.89(32.11)**	5.43(12.71)	9.42(12.63)
Sad 50%	13.04(19.75)	9.05(10.63)	**46.73(31.25)**	27.53(27.80)
Sad 75%	11.59(17.17)	8.33(8.33)	**52.53(29.13)**	23.91(24.65)
Sad 100%	11.59(15.83)	7.97(10.80)	**52.17(29.96)**	22.82(25.52)
Neutral	8.69(13.17)	14.13(11.90)	36.59(26.91)	**36.59(27.72)**

Note: No response accounts for missing data

Table B. 7 *Mean percentage (SD) of facial expressions classified correctly (in bold) and misclassifications per emotion and intensity in 6-year-olds.*

	6-year-olds' response			
Facial Expression	Angry	Happy	Sad	Neutral/ok
Angry 50%	**61.80(27.68)**	6.94(9.08)	13.54(17.51)	17.70(21.46)
Angry 75%	**88.88(16.60)**	3.12(8.08)	3.81(7.76)	4.16(6.95)
Angry 100%	**89.23(19.26)**	1.73(4.90)	4.51(9.51)	4.16(7.37)
Happy 50%	2.43(6.25)	**78.47(24.31)**	4.86(8.48)	14.23(22.85)
Happy 75%	2.43(6.25)	**90.97(14.72)**	3.12(7.29)	3.47(5.44)
Happy 100%	3.81(6.00)	**90.27(15.08)**	3.12(7.29)	2.77(7.23)
Sad 50%	5.55(11.43)	4.86(10.10)	**60.0(24.69)**	29.51(21.41)
Sad 75%	3.81(6.49)	5.55(11.17)	**67.70(26.72)**	22.91(22.15)
Sad 100%	5.55(6.80)	4.86(9.49)	**75.34(22.98)**	13.88(17.31)
Neutral	3.12(6.41)	6.59(13.45)	28.81(26.11)	**61.45(33.67)**

Note: Incorrect button press accounts for missing data

Table B. 8 *Mean percentage (SD) of facial expressions classified correctly (in bold) and misclassifications per emotion and intensity in 8-year-olds*

	8-year-olds' response			
Facial Expression	Angry	Happy	Sad	Neutral/ok
Angry 50%	**56.14(27.75)**	3.07(4.97)	13.59(13.09)	25.00(25.45)
Angry 75%	**85.96(20.61)**	3.50(7.51)	2.63(5.59)	6.14(10.70)
Angry 100%	**94.73(14.48)**	1.31(4.17)	1.75(5.94)	2.19(6.11)
Happy 50%	1.31(3.12)	**56.57(38.94)**	1.75(3.49)	29.82(35.60)
Happy 75%	2.19 (3.77)	**78.94(31.22)**	2.63(4.85)	5.70(11.12)
Happy 100%	1.75(4.46)	**84.64(30.71)**	1.75(3.49)	1.75(3.49)
Sad 50%	2.63 (6.24)	3.50(9.74)	**46.92(29.02)**	40.78(22.71)
Sad 75%	5.26(8.87)	2.19(6.11)	**62.71(30.09)**	28.94(25.66)
Sad 100%	6.57(9.03)	2.19(3.77)	**65.78(29.38)**	24.56(25.83)
Neutral	3.07(9.70)	3.07(5.69)	30.70(26.36)	**56.14(26.90)**

Note: Incorrect button press accounts for missing data

Table B. 9 *Mean percentage (SD) of facial expressions classified correctly (in bold) and misclassifications per emotion and intensity in the 10-year-olds.*

	10-year-olds' response			
Facial Expression	Angry	Happy	Sad	Neutral/ok
Angry 50%	**72.34(24.17)**	1.89(3.57)	15.15(20.99)	10.60(12.64)
Angry 75%	**94.31(8.67)**	.75(2.45)	3.03(6.57)	1.89(5.09)
Angry 100%	**98.86(2.92)**	.00(.00)	1.13(2.92)	.00(.00)
Happy 50%	3.40(6.63)	**71.59(29.17)**	2.27(4.58)	22.72(29.79)
Happy 75%	1.51(4.17)	**93.18(13.76)**	1.13(2.92)	4.16(12.79)
Happy 100%	1.89(4.40)	**95.83(8.43)**	1.51(4.17)	.37(1.77)
Sad 50%	.75(2.45)	1.51(4.17)	**53.03(23.64)**	44.69(23.78)
Sad 75%	1.13(2.92)	.37(1.17)	**69.31(22.76)**	29.16(22.82)
Sad 100%	1.13(2.92)	.75(2.45)	**82.19(18.94)**	15.90(18.34)
Neutral	.75(2.45)	1.89(4.40)	27.27(30.66)	**69.69(30.91)**

Note: Incorrect button press accounts for missing data

Table B. 10 *Mean percentage (SD) of facial expressions classified correctly (in bold) and misclassifications per emotion and intensity in adults.*

Facial Expression	Adults' Response			
	Angry	Happy	Sad	Neutral/ok
Angry 50%	**78.17(23.19)**	1.58(4.26)	9.52(16.30)	10.71(18.66)
Angry 75%	**96.82(4.91)**	1.98(3.63)	1.19(3.98)	.00(.00)
Angry 100%	**99.60(1.81)**	.00(.00)	.39(1.81)	.00(.00)
Happy 50%	2.38(4.67)	**92.06(10.02)**	.00(.00)	5.55(9.97)
Happy 75%	1.58(4.26)	**96.82(6.70)**	1.19(3.98)	.39(1.81)
Happy 100%	2.77(4.81)	**96.42(4.98)**	.79(2.50)	.00(.00)
Sad 50%	.39(1.81)	.00(.00)	**61.90(28.93)**	37.69(29.29)
Sad 75%	1.58(4.26)	1.19(3.98)	**85..31(18.61)**	11.90(18.36)
Sad 100%	.79(2.50)	.39(1.81)	**96.03(5.66)**	2.77(5.48)
Neutral	.00(.00)	.39(1.81)	6.34(10.83)	**93.25(10.74)**

Note: Incorrect button press accounts for missing data

Table B. 11 *Mean percentage (SD) of vocal expressions classified correctly (in bold) and misclassifications per emotion and intensity in preschoolers.*

Vocal Expression	Preschoolers' Response			
	Angry	Happy	Sad	Neutral/ok
Angry 50%	**20.65(16.64)**	23.18(18.96)	27.89(17.69)	20.28(19.59)
Angry 75%	**37.31(34.43)**	24.27(18.95)	23.55(15.82)	12.31(13.26)
Angry 100%	**38.40(34.60)**	23.18(21.75)	16.66(15.69)	18.11(19.05)
Happy 50%	22.46(18.87)	**31.52(19.77)**	24.27(20.24)	17.75(17.46)
Happy 75%	19.56(23.91)	**33.33(26.23)**	27.27(17.98)	17.39(23.69)
Happy 100%	17.75(20.45)	**38.40(29.59)**	20.28(16.44)	18.84(16.89)
Sad 50%	16.66(16.28)	26.44(19.56)	**31.52(23.83)**	19.20(14.95)
Sad 75%	18.47(19.12)	22.82(17.62)	**34.78(22.98)**	19.56(16.20)
Sad 100%	14.85(15.06)	27.17(18.83)	**35.50(19.17)**	18.11(13.91)
Neutral	15.57(17.28)	24.27(22.46)	32.60(22.17)	**21.73(19.09)**

Note: No response accounts for missing data

Table B. 12 *Mean percentage (SD) of vocal expressions classified correctly (in bold) and misclassifications per emotion and intensity in 6-year-olds.*

	6-year-olds' Response			
Vocal Expression	Angry	Happy	Sad	Neutral/ok
Angry 50%	**34.37(29.62)**	13.88(14.67)	32.63(17.87)	19.09(17.63)
Angry 75%	**78.12(30.47)**	7.63(14.93)	7.29(10.79)	6.94(10.89)
Angry 100%	**77.43(34.26)**	8.33(16.11)	6.59(10.70)	7.63(15.13)
Happy 50%	11.80(15.32)	**18.05(16.78)**	31.25(14.16)	38.88(25.26)
Happy 75%	12.84(15.53)	**58.33(32.22)**	16.66(14.32)	11.80(13.21)
Happy 100%	8.68(16.01)	**69.09(33.01)**	13.19(17.53)	9.02(9.49)
Sad 50%	6.94(13.15)	10.06(12.03)	**51.04(25.45)**	31.94(22.34)
Sad 75%	7.63(10.10)	10.06(12.99)	**50.00(29.38)**	32.29(24.36)
Sad 100%	9.02(12.26)	12.50(17.88)	**47.91(30.71)**	30.55(24.16)
Neutral	12.15(16.66)	9.37(13.52)	42.01(20.03)	**36.45(23.92)**

Note: Incorrect button press accounts for missing data

Table B. 13 *Mean percentage (SD) of vocal expressions classified correctly (in bold) and misclassifications per emotion and intensity in 8-year-olds.*

	8-year-olds' Response			
Vocal Expression	Angry	Happy	Sad	Neutral/ok
Angry50%	**21.92(21.73)**	9.21(17.32)	31.57(24.77)	34.21(23.71)
Angry75%	**82.45(23.71)**	8.33(21.15)	5.26(11.85)	3.50(7.51)
Angry100%	**80.70(27.78)**	9.64(24.09)	3.07(9.70)	5.26(8.43)
Happy50%	14.03(16.20)	**11.40(14.75)**	28.50(21.39)	42.10(28.39)
Happy75%	11.84(17.85)	**53.94(34.73)**	6.57(10.96)	19.29(16.44)
Happy100%	8.33(17.56)	**64.47(38.07)**	4.38(8.50)	13.15(14.51)
Sad50%	5.70(10.41)	7.01(14.23)	**42.54(31.16)**	37.28(23.63)
Sad75%	5.70(10.41)	8.33(15.21)	**46.92(34.38)**	32.01(21.74)
Sad100%	7.01(9.32)	7.45(12.07)	**41.22(29.32)**	35.94(21.52)
Neutral	13.59(15.76)	8.77(15.33)	36.84(27.95)	**35.52(23.21)**

Note: Incorrect button press accounts for missing data

Table B. 14 *Mean percentage (SD) of vocal expressions classified correctly (in bold) and misclassifications per emotion and intensity in 10-year-olds.*

	10-year-olds' Response			
Vocal Expression	Angry	Happy	Sad	Neutral/ok
Angry 50%	**35.98(34.92)**	9.09(14.29)	19.69(17.91)	35.22(30.53)
Angry 75%	**91.66(13.11)**	3.09 (9.10)	2.27(5.85)	3.03 (4.84)
Angry 100%	**89.39(20.44)**	6.43 (16.45)	3.03 (7.94)	1.13 (2.92)
Happy 50%	6.06(10.96)	**18.18(19.00)**	20.83(18.13)	54.92(26.18)
Happy 75%	4.16(6.68)	**75.35(29.03)**	9.46(16.72)	10.98(15.29)
Happy 100%	1.89(5.09)	**79.54(28.25)**	6.06(14.12)	12.50(18.32)
Sad 50%	3.03(7.06)	4.16(9.18)	**45.45(24.76)**	47.34(23.90)
Sad 75%	1.83(3.57)	5.75(12.57)	**49.62(32.27)**	40.90(28.85)
Sad 100%	1.89(6.26)	7.19(11.86)	**43.18(26.05)**	47.34(26.52)
Neutral	8.71(18.98)	6.81(13.27)	45.45(27.30)	**39.01(24.85)**

Note: Incorrect button press accounts for missing data

Table B. 15. *Mean percentage (SD) of vocal expressions classified correctly (in bold) and misclassifications per emotion and intensity in adults.*

	Adults' Response			
Vocal Expression	Angry	Happy	Sad	Neutral/ok
Angry 50%	**55.55(38.21)**	.39(1.81)	23.01(28.97)	21.03(28.70)
Angry 75%	**96.82(12.76)**	2.38(10.91)	.00(.00)	.79(2.50)
Angry 100%	**96.42(11.35)**	3.17(11.32)	.39(1.81)	.00(.00)
Happy 50%	1.58(4.26)	**18.25(23.95)**	8.33(12.63)	71.82(24.92)
Happy 75%	9.52(13.25)	**83.73(18.34)**	2.77(7.60)	3.96(6.24)
Happy 100%	1.58(3.35)	**94.84(8.11)**	.39(1.81)	3.17(6.70)
Sad 50%	.39(1.81)	.39(1.81)	**69.84(22.58)**	29.36(22.76)
Sad 75%	.39(1.81)	1.19(2.98)	**75.39(24.92)**	23.01(24.70)
Sad 100%	.00(.00)	.79(2.50)	**75.39(24.92)**	23.80(24.76)
Neutral	1.98(9.09)	1.19(3.98)	28.17(26.54)	**68.65(26.47)**

Note: Incorrect button press accounts for missing data

Table B. 16. *Partial Pearson's correlations (p value) between discrimination accuracy and child symptoms controlling for child age in the whole sample (N=88)*

	Child Psychopathology		
Accuracy	Hyperactivity	Conduct Problems	Emotional Problems
Face			
Angry 50%	**-.22 (.037)**	-.16(.157)	-.05(.657)
Angry 75%	-.13(.212)	-.12(.266)	-.04(.698)
Angry 100%	-.09(.387)	-.11(.303)	.02(.835)
Happy 50%	.06(.598)	.02(.888)	-.06(.537)
Happy 75%	-.13(.215)	-.05(.664)	-.13(.218)
Happy 100%	**-.23(.033)**	-.06(.587)	-.17(.108)
Sad 50%	**-.22(.041)**	-.14(.202)	-.12(.286)
Sad 75%	-.18(.098)	-.06(.572)	-.14(.191)
Sad 100%	**-.22(.042)**	-.10(.353)	**-.28(.009)**
Voice			
Angry 50%	.06(.554)	-.00(.956)	-.03(.797)
Angry 75%	.05(.628)	.00(.986)	.03(.763)
Angry 100%	.09(.359)	.10(.345)	.05(.663)
Happy 50%	.03(.776)	-.08(.448)	-.16(.134)
Happy 75%	-.17(.122)	-.06(.547)	-.02(.829)
Happy 100%	**-.22(.042)**	-.13(.214)	-.01(.895)
Sad 50%	.03(.759)	.04(.693)	-.00(.967)
Sad 75%	.03(.786)	-.00(.943)	-.06(.573)
Sad 100%	-.03(.808)	-.03(.777)	-.04(.743)

Table B. 17. *Partial Pearson's correlations (p value) between response bias and child symptoms controlling for child age in the whole sample (N=88)*

	Child Psychopathology		
Bias	Hyperactivity	Conduct Problems	Emotional Problems
Face			
Angry	-.09(.403)	-.03(.782)	-.14(.201)
Happy	**.28(.008)**	.05(.614)	.03(.754)
Sad	-.09(.370)	.09(.394)	.05(.642)
Voice			
Angry	.06(.598)	.13(.236)	-.01(.932)
Happy	-.04(.724)	-.08(.444)	-.02(.828)
Sad	-.16(.146)	**-.24(.024)**	-.01(.876)

Table B. 18. *Full Pearson's correlations (p value) between discrimination accuracy and adult psychopathology (N=21)*

	Adult Psychopathology		
Accuracy	Inattention	Hyperactivity	Internalising
Face			
Angry 50%	.24(.298)	-.10(.651)	-.30(.186)
Angry 75%	-.06(.809)	-.19(.407)	-.03(.907)
Angry 100%	-.39(.082)	**-.59(.005)**	-.10(.662)
Happy 50%	.27(.239)	**-.44(.046)**	-.25(.267)
Happy 75%	-.23(.325)	-.29(.201)	.05(.814)
Happy 100%	-.07(.762)	.01(.953)	-.08(.714)
Sad 50%	.18(.429)	-.07(.756)	-.26(.258)
Sad 75%	-.10(.652)	.25(.287)	.02(.914)
Sad 100%	-.04(.879)	.07(.776)	-.11(.621)
Voice			
Angry 50%	-.26(.268)	.15(.526)	-.17(.451)
Angry 75%	.35(.115)	-.35(129)	-.13(.580)
Angry 100%	.33(.145)	-.32(.160)	-.13(.585)
Happy 50%	.02(.940)	.33(.141)	-.04(.867)
Happy 75%	-.15(.509)	-.32(.161)	-.09(.702)
Happy 100%	.00(.978)	-.38(.098)	.32(.160)
Sad 50%	-.09(.678)	-.36(.111)	.09(.700)
Sad 75%	-.16(.506)	-.19(.390)	-.12(.599)
Sad 100%	-.13(.577)	.09(.701)	.06(.796)

Table B. 19. *Full Pearson's correlations (p value) between response bias and adult psychopathology*

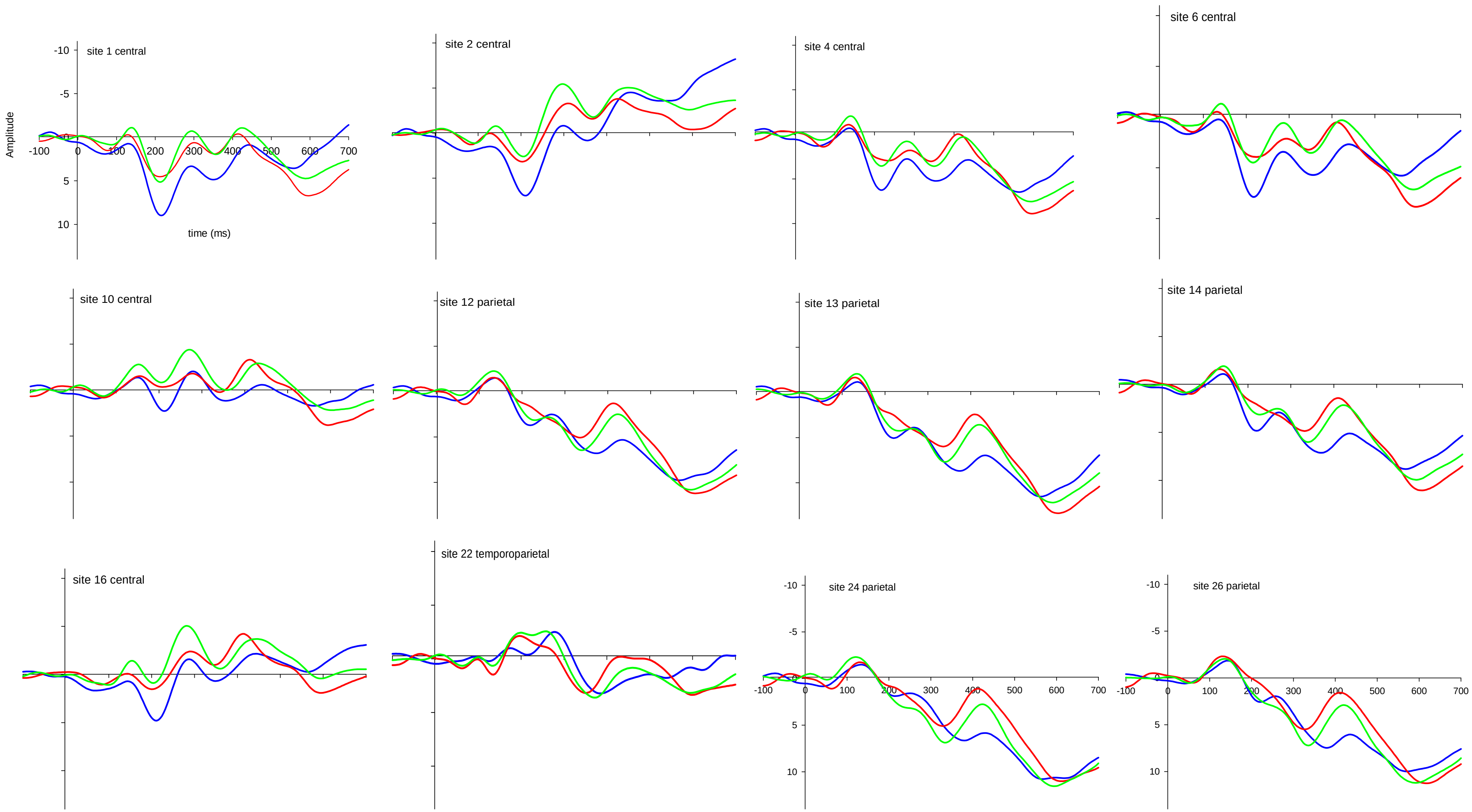
	Adult Psychopathology		
Bias	Inattention	Hyperactivity	Internalising
Face			
Angry	.31(.171)	**.62(.003)**	-.00(.982)
Happy	-.12(.387)	-.25(.277)	-.03(.870)
Sad	.42(.069)	.09(.688)	-.17(.470)
Voice			
Angry	-.02(.946)	.23(.315)	.08(.722)
Happy	-.33(.140)	.37(.094)	-.05(.815)
Sad	.01(.964)	-.26(.262)	**-.49(.025)**

APPENDIX C

Table C. 1. *Means (SD) of correct and artifact free ERP epochs per condition in the face and voice task in children excluded from ERP analyses*

	Angry	Happy	Neutral
Face			
Mean	22.10	20.80	12.90
SD	16.01	14.00	8.19
Voice			
Mean	16.60	16.18	12.60
SD	12.13	12.63	9.38

APPENDIX D -Study 4



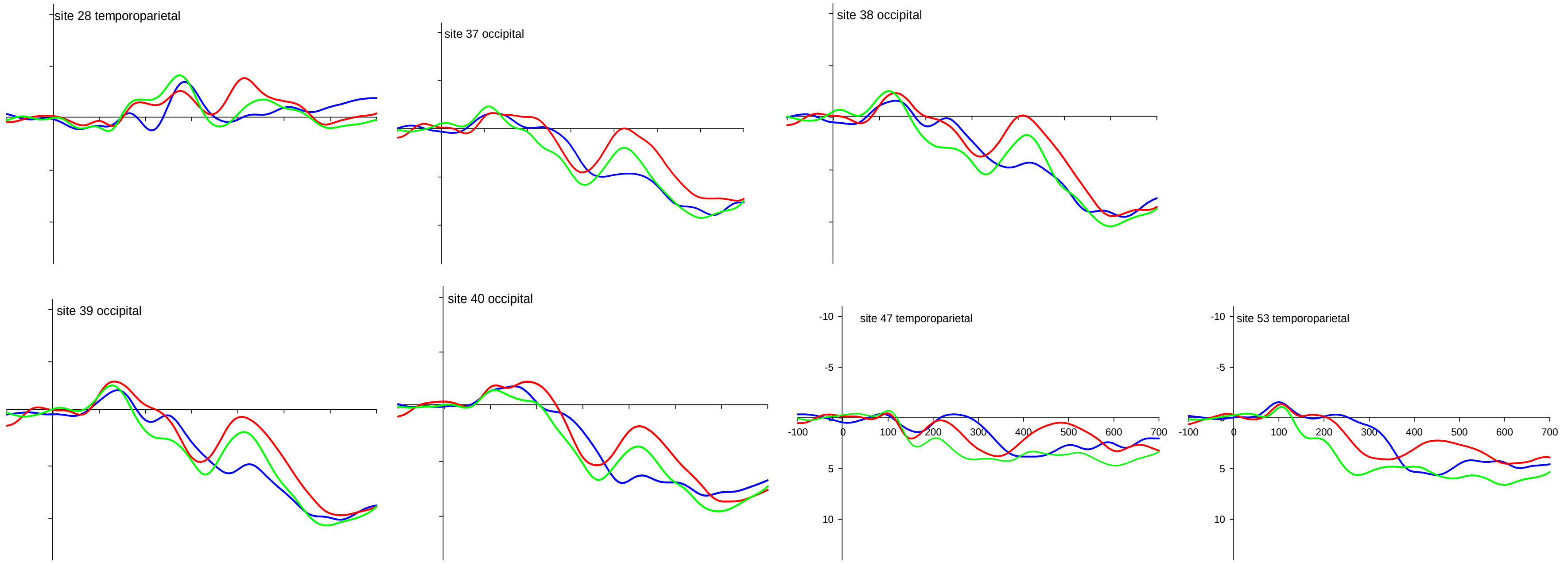


Figure D. 1. ERP Grand averages to voices at the 19 individual sites used in the EEG. Scale is -11 to + 14 μV. Angry Happy Neutral

Table D. 1. *Spearman's correlations (p values) between performance and an A-N (angry minus neutral) amplitude difference score to vocal expressions (N=60)*

	Accuracy			Bias		
ERP	Angry	Happy	Neutral	Angry	Happy	Neutral
Central N1	-.17(.197)	-.02(.903)	-.15(.259)	-.03(.822)	-.05(.678)	-.22(.122)
Central P2	-.12(.344)	-.06(.659)	-.07(.602)	-.09(.500)	.16(.211)	-.10(.420)
Central P3	.02(.847)	.05(.675)	.07(.574)	.03(.826)	.19(.130)	-.10(.448)
Central N400	.15(.264)	.08(.555)	.05(.689)	.22(.091)	**.33(.011)**	-.22(.099)
Occipital N400	.10(.443)	.00(.986)	.00(.972)	.17(.198)	.12(.344)	-.14(.291)
Parietal N400	.15(.264)	.08(.541)	.07(.578)	.19(.136)	.19(.128)	-.20(.126)
TemoroPar N400	.19(.155)	.09(.896)	.05(.717)	**.29(.025)**	.19(.153)	-.18(.164)

Table D. 2. *Spearman's correlations (p value) between child psychopathology and performance (N=60)*

	Accuracy			Bias		
Child Symptoms	Angry	Happy	Neutral	Angry	Happy	Neutral
Hyperactiviy	.03(.835)	-.04(.787)	-.20(.120)	.25(.054)	-.00(.952)	-.24(.060)
Conduct	.00(.994)	-.08(.533)	-.16(.231)	.12(.344)	-.10(.439)	.02(.860)
Anxiety	.16(.218)	.15(.257)	.14(.304)	**.26(.048)**	.07(.586)	-.13(.334)
Depression	.089(.511)	.19(.164)	.13(.340)	.13(.338)	.09(.515)	-.09(.484)
Emotion Dysregulation	-.08(.568)	-.06(.667)	-.14(.287)	.05(.720)	-.09(.517)	.00(.955)

Table D. 3. *Full Pearson's correlations (p values) between child psychopathology and ERPs to vocal expressions (N=60)*

	Child Psychopathology				
ERP	Hyperactivity	Conduct	Emotion Dysregulation	Anxiety	Depression
Central N1					
Angry	-.09(.484)	**-.27(.035)**	**-.29(.026)**	**-.36(.005)**	**-.38(.003)**
Happy	-.07(.581)	-.04(.790)	-.12(.358)	-.16(.222)	-.16(.230)
Neutral	.02(.897)	-.09(.475)	-.14(.303)	-.24(.067)	**-.29(.028)**
Central P2					
Angry	.06(.672)	-.12(.346)	-.13(.321)	**-.28(.036)**	**-.29(.023)**
Happy	-.04(.768)	.05(.684)	-.09(.490)	-.14(.285)	-.19(.146)
Neutral	.23(.082)	.09(.460)	.03(.827)	-.07(.621)	-.17(.216)
Central P3					
Angry	-.00(.943)	-.10(.420)	-.07(.622)	.00(.993)	-.10(.455)
Happy	-.05(.679)	.06(.652)	-.03(.791)	-.09(.478)	-.13(.337)
Neutral	.12(.352)	.06(.655)	.07(.597)	.08(.536)	-.02(.898)
Central N400					
Angry	-.07(.576)	-.18(.164)	-.19(.140)	-.05(.712)	-.08(.570)
Happy	-.17(.188)	-.09(.496)	-.13(.323)	-.18(.177)	-.26(.047)
Neutral	-.06(.654)	-.07(.621)	-.01(.925)	-.15(.276)	-.19(.136)
Parietal N400					
Angry	-.12(.347)	**-.34(.007)**	-.25(.053)	-.21(.114)	-.20(.115)
Happy	-.23(.084)	-.22(.088)	-.17(.206)	-.16(.237)	-.17(.213)
Neutral	-.14(.297)	-.23(.077)	-.09(.475)	-.12(.143)	-.19(.149)
Occipital N400					
Angry	-.13(.340)	**-.42(.001)**	**-.27(.036)**	-.19(.138)	-.19(.156)
Happy	-.16(.224)	**-.28(.033)**	-.18(.377)	-.06(.682)	-.00(.959)
Neutral	-.02(.869)	-.22(.077)	-.02(.919)	-.10(.450)	-.04(.803)
Temporopar N400					
Angry	-.18(.174)	**-.39(.001)**	**-.32(.014)**	.05(.694)	.03(.820)
Happy	-.24(.070)	**-.28(.033)**	-.22(.096)	-.04(.768)	-.05(.732)
Neutral	-.07(.599)	-.20(.111)	-.03(.847)	-.05(.715)	-.01(.914)

Table D. 4 *Spearman's correlations between parent characteristics and child performance (N=60)*

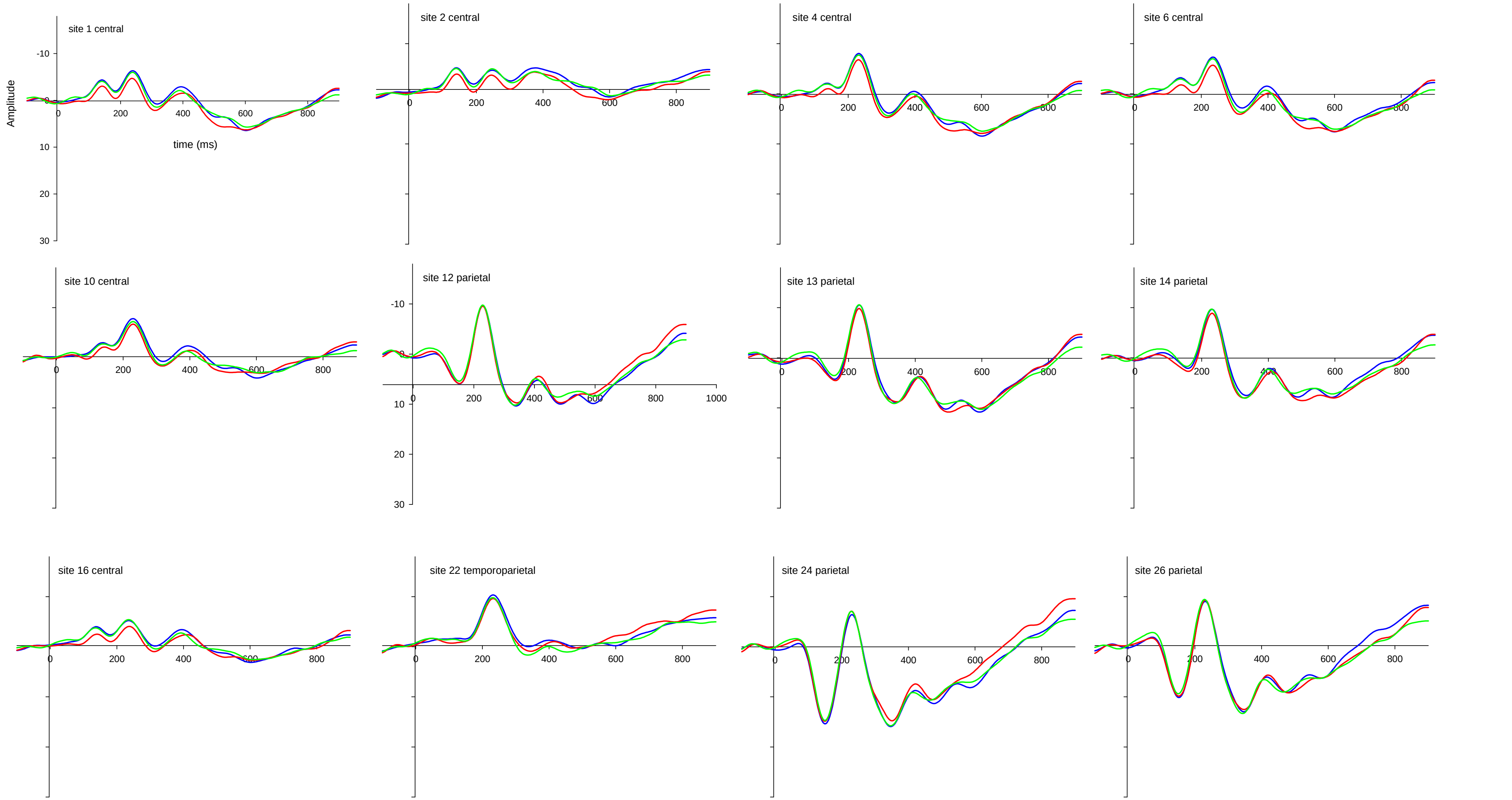
Parent Symptoms	Accuracy			Bias		
	Angry	Happy	Neutral	Angry	Happy	Neutral
Depression	-.15(.238)	-.02(.898)	-.08(.525)	-.01(.922)	.09(.498)	-.13(.322)
Inattentive	.04(.783)	.09(.482)	.00(.993)	.18(.178)	.17(.207)	-.22(.092)
Hyperactive	.07(.575)	.08(.542)	.07(.621)	.10(.442)	-.02(.896)	-.11(.388)
Satisfaction	**.26(.047)**	**.26(.049)**	.22(.097)	.18(.184)	-.03(.818)	-.03(.824)
Self-Efficacy	-.04(.777)	-.04(.743)	-.01(.915)	.21(.104)	.09(.487)	-.08(.535)
PSOC	.13(.318)	.15(.255)	.14(.306)	.25(.053)	.09(.501)	-.13(.355)

Note: PSOC=Parenting Sense of Competence

Table D.5. *Full Pearson's correlations (p value) between parental psychopathology and children's ERPs to vocal expressions (N=60)*

	Parent Psychopathology			
ERP	Inattention	Hyperactivity	ADHD combined type	Depression
Central N1				
Angry	-.00(.964)	-.01(.896)	-.01(.925)	-.00(.994)
Happy	.05(.682)	-.05(.699)	.00(.967)	.02(.854)
Neutral	-.09(.465)	.05(.680)	-.02(.827)	-.23(.077)
Central P2				
Angry	.05(.701)	**.27(.039)**	.16(.196)	-.07(.603)
Happy	.09(.480)	-.03(.818)	.04(.766)	.16(.216)
Neutral	.04(.749)	.14(.284)	.01(.456)	-.01(.454)
Central P3				
Angry	.21(.104)	**.30(.018)**	**.28(.028)**	-.15(.241)
Happy	.09(.487)	.00(.964)	.05(.664)	.03(.802)
Neutral	.06(.670)	.22(.093)	.14(.263)	-.18(.153)
Central N400				
Angry	.08(.545)	.14(.290)	.12(.363)	**-.26(.045)**
Happy	.05(.676)	.09(.499)	.08(.549)	.01(.933)
Neutral	.02(.860)	.14(.289)	.09(.513)	-.21(.108)
Occipital N400				
Angry	-.05(.707)	.01(.894)	-.02(.878)	**-.27(.036)**
Happy	.03(.817)	.07(.579)	.05(.671)	-.16(.208)
Neutral	.01(.940)	.15(.265)	.08(.534)	-.20(.115)
Parietal N400				
Angry	.02(.862)	.07(.610)	.05(.713)	**-.26(.040)**
Happy	.05(.702)	.07(.578)	.06(.606)	-.11(.387)
Neutral	-.03(.813)	.12(.375)	.04(.749)	**-.26(.044)**
TempParN400				
Angry	-.00(.946)	.14(.284)	.06(.607)	**-.30(.019)**
Happy	.02(.863)	.01(.938)	.01(.887)	-.14(.290)
Neutral	.03(.821)	.13(.300)	.08(.501)	**-.27(.038)**

APPENDIX E –Study 5



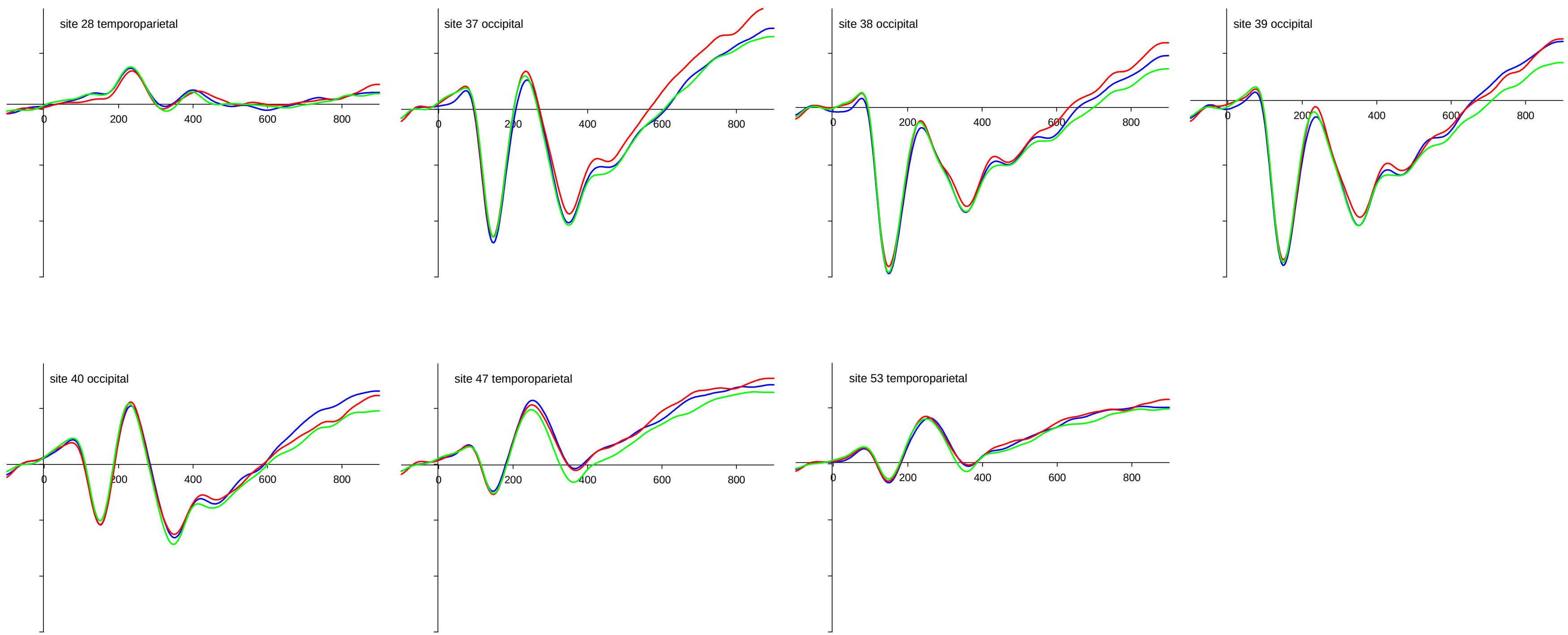


Figure E. 1. ERP Grand averages to faces at the 19 individual sites used in the EEG. Scale is -18 to +30 µV. Angry Happy Neutral

Table E. 1. *Spearman's correlations (p value) between child psychopathology and performance*

	Accuracy			Response Bias		
Child symptoms	Angry	Happy	Neutral	Angry	Happy	Neutral
Hyperactivity	-.23(.069)	**-.29(.017)**	**-.27(.030)**	-.09(.448)	-.04(.754)	-.02(.861)
Conduct	-.18(.149)	**-.29(.021)**	-.15(.224)	-.15(.227)	-.02(.899)	.15(.214)
Anxiety	-.16(.204)	-.13(.302)	.00(.999)	-.13(.322)	-.02(.872)	.16(.212)
Depression	-.10(.436)	-.09(.442)	.04(.760)	-.10(.398)	-.09(.480)	.23(.068)
Emotion Dysregulation	-.15(.265)	-.20(.111)	-.07(549)	-.12(.369)	-.07(.564)	.09(.482)

Table E. 2. *Partial Pearson's correlations (p value) between performance and central ERPs to faces after controlling for child age (N=63).*

	Accuracy Angry	Accuracy Happy	Accuracy Neutral	Bias Angry	Bias Happy	Bias Neutral
Central P1 amp						
Angry	-.09(.445)	-.06(.657)	-.10(.403)	-.03(.793)	.01(.926)	-.04(.762)
Happy	.00(.964)	-.00(.969)	-.02(.844)	.17(.194)	-.18(.174)	-.08(.550)
Neutral	.09(.495)	.06(.663)	.08(.558)	-.01(.915)	-.09(.459)	.03(.839)
Central P1 lat						
Angry	-.09(.464)	-.05(.675)	-.09(.456)	-.10(.433)	**.29(.024)**	-.15(.237)
Happy	.15(.261)	**.22(.081)**	.19(.150)	-.11(.379)	.15(.252)	.09(.508)
Neutral	-.05(.720)	-.07(.611)	-.09(.510)	.09(.506)	-.07(.583)	.00(.997)
Central N170						
Angry	**-.24(.056)**	-.15(.254)	**-.25(.049)**	-.12(.365)	.23(.078)	-.08(.527)
Happy	-.12(.347)	-.02(.872)	-.09(.455)	-.15(.260)	.12(.360)	.06(.662)
Neutral	-.18(.166)	-.11(.375)	-.17(.195)	-.21(.098)	.10(.428)	.15(.247)
Central N170 lat						
Angry	-.09(.466)	-.08(.525)	-.04(.771)	.06(.654)	-.15(.232)	-.04(.760)
Happy	.15(.241)	.17(.189)	.12(.342)	.17(.181)	-.17(.188)	-.13(.316)
Neutral	.08(.518)	.10(.431)	.13(.301)	.03(.826)	-.09(.447)	-.02(.848)
Central P300						
Angry	-.02(.883)	.00(.990)	-.06(.637)	-.00(.953)	.10(.441)	-.13(.325)
Happy	.04(.751)	.03(.792)	.03(.843)	-.05(.698)	-.05(.707)	.06(.666)
Neutral	.04(.761)	.03(.815)	.02(.864)	-.08(.526)	-.02(.893)	.10(.441)
Central ESW						
Angry	.00(.971)	-.00(.952)	-.05(.722)	.09(.461)	-.00(.960)	-.15(.235)
Happy	.02(.845)	-.00(.990)	.01(.915)	.00(.944)	-.11(.384)	.05(.671)
Neutral	.04(.733)	.05(.728)	.03(.801)	.01(.928)	-.08(.556)	.01(.911)
Central LSW						
Angry	.02(.892)	.02(.864)	.01(.935)	-.02(.852)	.07(.608)	-.10(.430)
Happy	.01(.938)	-.01(.913)	.00(.971)	-.02(.859)	-.07(.580)	.02(.865)
Neutral	.06(.667)	.04(.786)	.05(.683)	-.05(.724)	-.01(.921)	-.00(.950)

Table E. 3. *Partial Pearson's correlations (p value) between performance and parietal ERPs to faces controlling for child age (N=63).*

	Accuracy Angry	Accuracy Happy	Accuracy Neutral	Bias Angry	Bias Happy	Bias Neutral
Parietal P1 amp						
Angry	.14(.286)	.22(.089)	.09(.451)	.01(.926)	.10(.411)	-.09(.486)
Happy	.22(.088)	**.29(.023)**	.16(.207)	.09(.481)	.04(.772)	-.05(.730)
Neutral	**.25(.050)**	**.26(.041)**	.22(.085)	.01(.924)	.13(.327)	-.01(.931)
Parietal P1 lat						
Angry	.01(.909)	.08(.559)	-.05(.719)	.04(.760)	**.27(.035)**	**-.24(.066)**
Happy	**.24(.058)**	**.32(.011)**	**.24(.063)**	-.01(.935)	.12(.353)	.05(.716)
Neutral	.10(.400)	.09(.488)	-.00(.970)	.15(.253)	-.05(.720)	-.03(.837)
Parietal N170 amp						
Angry	-.18(.165)	-.11(.388)	-.17(.204)	-.02(.902)	.22(.082)	-.04(.754)
Happy	-.14(.277)	-.05(.698)	-.12(.365)	-.08(.523)	.08(.520)	.09(.473)
Neutral	-.15(.252)	-.12(.352)	-.12(.374)	-.12(.355)	.13(.323)	.18(.165)
Parietal N170 lat						
Angry	.10(.437)	.05(.698)	.13(.335)	.17(.189)	-.03(.800)	.43(-.102)
Happy	.14(.276)	.13(.328)	.06(.669)	.19(.129)	-.10(.411)	-.13(.329)
Neutral	.16(.208)	.13(.302)	.14(.266)	.18(.161)	-.12(.349)	-.07(.607)
Parietal P300						
Angry	.10(.409)	.132(.309)	.10(.424)	.07(.602)	.03(.796)	-.09(.499)
Happy	.10(.423)	.10(.414)	.13(.332)	-.02(.902)	-.12(.316)	.13(.323)
Neutral	.19(.142)	.18(.157)	.21(.099)	.00(.974)	-.066(.610)	.14(.272)
Parietal Early Slow Wave						
Angry	.05(.715)	.05(.690)	.03(.799)	.19(.147)	-.030(.819)	-.18(.154)
Happy	.06(.649)	.05(.696)	.08(.572)	.07(.594)	-.154(.231)	.07(.567)
Neutral	.14(.264)	.15(.241)	.15(.241)	.12(.352)	-.076(.557)	-.02(.865)
Parietal Late Slow Wave						
Angry	.02(.897)	.05(.670)	.05(.709)	.05(.692)	.06(.634)	-.14(.267)
Happy	.02(.878)	.02(.902)	.02(.856)	.04(.789)	-.09(.458)	.01(.928)
Neutral	.09(.489)	.10(.439)	.09(.502)	.07(.609)	-.00(.985)	-.10(.416)

Table E. 4. *Partial Pearson's correlations (p value) between performance and occipital ERPs to faces controlling for child age (N=63).*

	Accuracy Angry	Accuracy Happy	Accuracy Neutral	Bias Angry	Bias Happy	Bias Neutral
Occipital P1 amp						
Angry	.22(.092)	**.28(.027)**	.12(.343)	.07(.598)	.06(.652)	.00(.969)
Happy	.22(.087)	**.29(.020)**	.16(.224)	.04(.782)	.03(.826)	.10(.406)
Neutral	**.25(.050)**	**.27(.031)**	.18(.155)	.04(.733)	.09(.502)	.09(.331)
Occipital P1 lat						
Angry	.03(.835)	.04(.762)	-.03(.835)	.09(.491)	**.23(.071)**	-.07(.610)
Happy	.05(.706)	.09(.499)	.04(.758)	-.09(.462)	.11(.374)	.14(.283)
Neutral	-.04(.763)	-.02(.858)	-.06(.653)	.12(.363)	.05(.687)	-.00(.984)
Occipital N170 amp						
Angry	-.05(.701)	-.10(.440)	-.15(.248)	.11(.374)	-.02(.888)	.08(.537)
Happy	-.04(.740)	-.06(.628)	-.09(.453)	-.03(.828)	-.11(.397)	**.23(.039)**
Neutral	-.01(.935)	-.07(.595)	-.05(.674)	.02(.900)	-.07(.589)	**.25(.046)**
Occipital N170 lat						
Angry	.00(.963)	.06(.658)	-.07(.598)	-.01(.926)	.09(.449)	.00(.948)
Happy	.12(.345)	.20(.109)	.12(.370)	-.02(.865)	.07(.560)	-.03(.792)
Neutral	.11(.377)	.10(.425)	.06(.661)	-.01(.938)	.04(.771)	.03(.831)
Occipital P300						
Angry	.17(.180)	.19(.146)	.14(.273)	.16(.212)	-.09(.452)	-.04(.782)
Happy	.09(.472)	.08(.525)	.09(.504)	.04(.761)	**-.23(.074)**	.18(.160)
Neutral	**.23(.067)**	**.23(.071)**	**.25(.049)**	.09(.502)	-.17(.178)	.18(.175)
Occipital Early Slow Wave						
Angry	.08(.527)	.07(.568)	.06(.643)	**.26(.045)**	-.06(.645)	-.09(.465)
Happy	.01(.930)	-.03(.846)	.04(.983)	.08(.551)	-.17(.176)	.15(.244)
Neutral	.19(.129)	.18(.170)	.19(.130)	.19(.123)	-.15(.257)	.06(.642)
Occipital Late Slow Wave						
Angry	.06(.629)	.08(.563)	.07(.590)	.18(.171)	-.00(.993)	-.09(.512)
Happy	-.00(.993)	-.02(.896)	-.02(.908)	.11(.387)	-.15(.241)	.07(.585)
Neutral	.11(.390)	.10(.439)	.09(.494)	.19(.129)	-.06(.625)	-.04(.750)

Table E. 5. *Partial Pearson's correlations (p value) between performance and temporoparietal ERPs to faces controlling for child age (N=63).*

	Accuracy Angry	Accuracy Happy	Accuracy Neutral	Bias Angry	Bias Happy	Bias Neutral
TemporoParietal P1 amp						
Angry	-.05(.682)	-.04(.750)	-.11(.377)	.09(.451)	.02(.883)	-.15(.253)
Happy	.08(.534)	.07(.582)	-.00(.992)	.09(.497)	-.05(.702)	.07(.582)
Neutral	.06(.656)	-.02(.896)	-.02(.901)	.12(.353)	.02(.868)	-.02(.847)
TemporoParietal P1 lat						
Angry	-.06(.646)	-.03(.823)	-.08(.544)	.01(.939)	.28(.026)	-.17(.199)
Happy	.04(.766)	.08(.516)	.00(.975)	-.04(.770)	.11(.378)	.02(.855)
Neutral	-.07(.578)	-.12(.357)	-.12(.355)	.12(.345)	.00(.996)	-.02(.862)
TemporoParietal N170 amp						
Angry	-.22(.092)	**-.25(.047)**	**-.25(.051)**	-.02(.883)	.20(.108)	-.02(.850)
Happy	-.14(.276)	-.14(.270)	-.13(.300)	-.19(.136)	.02(.877)	**.28(.028)**
Neutral	-.16(.209)	-.20(.110)	-.17(.188)	-.15(.250)	.09(.456)	**.27(.038)**
TemporoParietal N170 lat						
Angry	-.04(.784)	-.03(.831)	-.06(.666)	**.25(.051)**	-.12(.336)	-.16(.208)
Happy	.14(.281)	.19(.124)	.12(.358)	.14(.270)	-.04(.768)	-.12(.358)
Neutral	.13(.321)	.18(.175)	.10(.402)	.10(.432)	.05(.698)	-.15(.254)
TemporoParietal P300						
Angry	.00(.965)	-.05(.729)	-.04(.732)	.07(.601)	.05(.677)	-.09(.486)
Happy	-.03(.790)	-.09(.503)	-.05(.706)	-.03(.803)	-.08(.525)	.14(.265)
Neutral	.04(.773)	-.00(.977)	.03(.848)	-.02(.858)	-.02(.856)	.15(.257)
TemporoParietal ESW						
Angry	-.04(.758)	-.10(.412)	-.10(.437)	.16(.213)	.03(.793)	-.14(.268)
Happy	-.08(.558)	-.13(.301)	-.09(.485)	.03(.812)	-.09(.447)	.09(.458)
Neutral	.05(.705)	-.00(.990)	.00(.971)	.11(.377)	-.07(.609)	.02(.855)
TemporoParietal LSW						
Angry	.00(.996)	-.06(.633)	-.03(.818)	.13(.300)	.03(.801)	-.12(.337)
Happy	-.09(.517)	-.14(.286)	-.11(.396)	.05(.729)	-.09(.469)	.05(.701)
Neutral	.03(.805)	-.04(.755)	-.02(.906)	.10(.411)	-.05(.710)	-.03(.829)

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