Development of a novel EEG paradigm to investigate the neural correlates of children's emotion understanding

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Thesis declaration form

I confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Overview

Emotion understanding is a key foundation of social skills (e.g. Denham et al., 2003; Izard et al., 2001) and thus research into its determinants is a potentially important area for clinical and developmental psychology. This thesis investigates the development of emotion understanding in young children.

Part one is a literature review of 23 papers examining the relationship between attachment and emotion understanding in children. A summary of the papers is presented, before reflections on the meaning of the results. Overall, secure attachment appears to be related to superior emotion understanding. However, larger, well-controlled studies are needed to better understand the association.

Part two presents an empirical paper focused on the development of a novel Electroencephalogram (EEG) paradigm to investigate emotion understanding in 6-year-old children. The children tested formed part of a cohort of children who had taken part in a previous study, in which their attachment to their primary care-giver was profiled. The study is the first to demonstrate Event Related Potentials (ERPs) associated with emotion understanding in young children. Specifically, a Late Positive Potential (LPP) was found to be an index of emotion understanding. The paper investigates associations between ERPs and social competence measures, and with security of attachment. The empirical research was undertaken with Sarah Carman (Carman, 2013).

Part three provides a critical appraisal of the research process. It considers difficulties encountered in producing externally valid research. Issues in the development of the EEG paradigm, methodological difficulties in ERP research, and measure selection are discussed.

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Part 1: Literature Review

The relationship between attachment and emotion understanding in young children

Abstract

Aims

Emotion understanding is a key foundation of social skills (e.g. Denham et al., 2003; Izard et al., 2001) and researchers have suggested that the attachment relationship is fundamental in its development (e.g. Harris, 1999). The present paper aimed to synthesise and critically appraise the literature investigating this association.

Methods

Literature databases were searched for studies in peer reviewed journals that investigated the relationship between attachment and emotion understanding.

Results

Twenty-three papers based on twenty-one independent studies were reviewed. Seventeen studies reported a relationship between mother-child attachment pattern and emotion understanding. In general, secure attachment patterns were related to enhanced emotion understanding. Methodological design and measures of constructs were variable.

Discussion

There is evidence for an association between attachment and emotion understanding. Studies investigating maternal mind-mindedness and maternal mental state language have found that these may be important mediators. Larger, well-controlled studies are needed to better understand the relationship.

Emotion understanding (or affective mentalising) refers to the ability to accurately predict or understand a person's emotional response based on our understanding of the context that the person is in (e.g. Thompson, 1989). Clearly, emotion understanding is likely to depend upon emotion recognition, which has been subjected to extensive research (e.g. Collin, Bindra, Raju, Gillberg & Minnis, 2013; Harms, Martin & Wallace, 2010; Herba and Phillips, 2004). However, emotion recognition is just one element of the more complex ability to not just recognise emotions, but read behaviour and contexts in such a way that someone's emotional response can be predicted and understood.

Emotion understanding is related to cognitive Theory of Mind, which refers to the ability to understand that other people have thoughts about a situation and that others' cognitions may be different to one's own (e.g. Baron-Cohen, 1991). This is typically measured with tasks of false-belief, which require an understanding that it is possible for a person to hold a belief about a situation that is different from the reality of that situation. In addition, emotion understanding (or emotional Theory of Mind) involves knowing that others have inner emotional states that are triggered by different contexts and the meanings associated with them, and that emotions imply certain behavioural dispositions (e.g. Weimer, Sallquist & Bolnick, 2012).

As emotion understanding is related to a number of different concepts, so the development of emotion understanding is not an all-or-nothing shift from 'mind-blindness' (Baron-Cohen, 1990) to mind-reader. According to the theory of Belief-Desire Psychology (e.g. Astington, Harris & Olson, 1990; Wellman, 1990), young children first learn that actions are informed by a person's desires (i.e. motivation), before learning that a person's beliefs (i.e. knowledge of a situation) can guide their actions (see Wellman & Liu, 2004 for a meta-analysis).

Harris, Johnson, Hutton, Andrews and Cooke (1989) suggest that 3-year-old children are able to understand how desires relate to emotional responses (e.g. you want an ice-cream + there is no ice cream = you feel sad), but that at around aged

5, children are able to combine their knowledge of desires *and beliefs* to understand another person's emotional reaction. Thus, understanding whether someone feels happy or sad about a false-belief situation requires both knowing what they want (desires) and whether they believe that they will get they will get what they want (i.e. that person will be happy because *they* think they are getting ice-cream, which they like, even though I know that the box is empty; Harris et al., 1989). Similarly, children are able to understand emotions based on desire, such as happiness and sadness, before they can understand emotions based on beliefs, such as surprise (e.g. Hadwin & Perner, 1991; Wellman & Banerjee, 1991; Wellman & Bartsch, 1988). Hence, according to this view, more complex emotion understanding is dependent on a prior understanding of Theory of Mind.

Fonagy and Target (1997) suggest that the ability to attribute mental states (cognitions and emotions) to others allows children to ascribe meaning to another's behaviour and to predict that behaviour. They explain that "as children learn to understand people's behaviour, they can flexibly activate, from multiple sets of self-other representations organised on the basis of prior experience, the one(s) best suited to respond adaptively to particular interpersonal transactions" (Fonagy & Target, 1997, p. 680). Thus, emotion understanding should be a key foundation of social skills, and indeed young children's emotional competence has been shown to contribute later social competence (e.g. Denham et al, 2003; Izard et al, 2001). Therefore, research into its determinants is a potentially important area for clinical and developmental psychology.

Emotion understanding and attachment

In a review of studies investigating individual differences in understanding emotion, Harris (1999) delineated two models of the development of emotion understanding: the 'Psychological Discourse Model', in which care-giver variation in discourse regarding emotion (i.e. the "manner and/or extent that feelings are put into words";

Harris, 1999, p. 307), affects the way that a child is able to 'encode' emotional events; and the 'Attachment Status Model', in which attachment security is directly related to children's emotion understanding (Figure 1).

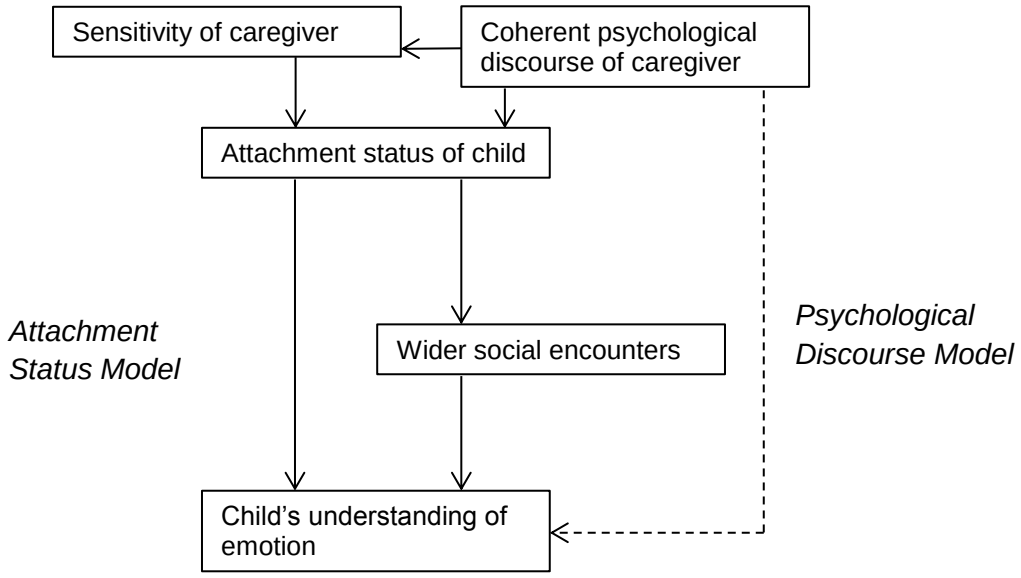

Figure 1. Flow diagram illustrating potential models of the development of emotion understanding, from Harris (1999). Solid lines indicate causal relationships within the 'Attachment Status Model' and the dashed line indicates the causal relationship between psychological discourse and emotion understanding in the 'Psychological Discourse Model'.

According to the Psychological Discourse model, children who are in environments in which emotions and mental states are discussed, have greater understanding of mental states (see also Denham, Zoller & Couchoud, 1994; Meins, 1999). Symons (2004) posits that this occurs through a process of internalisation (as discussed by Lloyd & Fernyhough, 1999; Vygotsky, 1978), in which "some representational understanding of the language also takes place" (p. 167). Language thus provides a route by which emotional situations can be organised and appraised. Eventually, the child is able to provide structure to emotional events in the absence of another person's discourse (Symons, 2004).

Within the Attachment Status Model, variation in caregiver sensitivity is related to the mother-infant attachment relationship (e.g. de Wolff & van Ijzendoorn,

1997; van IJzendoorn, Juffer & Duyvesteyn, 1995). Sensitive parents are able to notice their child's needs and respond appropriately (Ainsworth, Blehar, Waters & Wall, 1978). Although this model includes psychological discourse, it links this to caregiving sensitivity and attachment status, but not directly to emotion understanding. Thus, within this model, attachment status is presumed to be the key causal link associated with individual differences in emotion understanding. Harris (1999) postulated that the relationship between attachment status and emotion understanding may then be either direct, or mediated through another variable, such as 'wider social encounters' (Figure 1); i.e. securely attached children are likely to have more friends and thus more opportunities for learning about emotion within the social environment.

Fonagy and Target (1997) propose that within a secure attachment relationship, the caregiver is able to reflect back the infant's mental state. Over time, the infant learns that the caregiver's reaction is related to the infant's own internal state (beliefs or desires). Accordingly, within a secure attachment relationship, the caregiver will both "recognise and reflect back the child's experience" (Harris, 1999, p. 315), and "help the child contain and cope with that experience" (Harris, 1999, p. 315). According to this proposal, children with secure attachments thus feel safer to explore negative emotions, as they are able to better cope with them (Fonagy & Target, 1997).

On this basis, Harris (1999) hypothesised that differences between securely and insecurely attached children in emotion understanding should be thus more apparent in situations that may be threatening or anxiety provoking (i.e. in situations in which the attachment system may be activated), and that securely attached children should perform better in these situations (the 'diminished lexicon for emotion' hypothesis). Consistent with this theory, Laible and Thompson (1998) found secure attachment to be associated with better understanding of negative, but not positive, emotions. However, this was only true of one specific facet of emotion

understanding; being able to explain the reasons behind the emotion. It was not related to accurate emotion recognition. In contrast to Harris' hypothesis, Belsky, Spritz and Crnic (1996) have suggested that insecurely attached children experience more negative events and are therefore more attuned to negative emotions. This may suggest that insecurely attached children should perform better on tests of the understanding of negative emotions (the 'hypervigilance' hypothesis).

Harris (1999) suggested that "there is some way to go before the proposed relationship between attachment security and emotion understanding is established and understood" (p. 315). Since that time, a number of studies have further investigated the relationship, using experimental and observational paradigms, and these have begun to be collated into reviews (e.g. Pavarini, de Hollanda Souza & Hawk, 2012; Symons, 2004).

In a narrative review of the development of Theory of Mind, Symons (2004) summarised the results of studies investigating the relationship between attachment status and Theory of Mind. He discussed that although self-other understanding has been show to relate to concurrent attachment pattern, there is less evidence of this in longitudinal studies, which investigate early attachment security and later social understanding. Rather, he suggests that common parenting processes underlying attachment and Theory of Mind, such as parental discourse and maternal mind-mindedness, are key in the development of social understanding.

Similarly, a recent systematic review investigating parental practices and Theory of Mind development, including 18 studies related to attachment, found that children with secure attachment relationships were better at false-belief and emotion comprehension tasks than children with insecure attachment relationships (Pavarini et al., 2012), but that mediating variables need to be taken into consideration. Moreover, the authors state that discourse about mental state, past events, and maternal mind-mindedness (mother's awareness of their child's mental states; Meins, 1997) have all been found to mediate, moderate and in some cases fully

explain, the relationship between attachment and Theory of Mind development (e.g. Laranjo, Bernier, Meins & Carlson, 2010; McQuaid, Bigelow, McLaughlin & MacLean, 2008; Meins et al., 2002; Ontai & Thompson, 2008; Raikes and Thompson, 2006).

Pavarini and colleagues (2012) suggest that, given these findings, "it seems more fruitful to focus on specific features of parent-child interaction on children's understanding of mental states, rather than general effects of attachment on theory-of-mind development" (p. 3). They therefore discuss studies investigating the effect of maternal sensitivity and maternal discourse styles, as opposed to attachment security, on emotion understanding for the remainder of their review. However, we consider that there is good reason to continue to investigate the relationship between attachment and emotion understanding. Firstly, Pavarini and colleagues (2012) cite only five studies that found effects of other parenting variables, to explain the attachment relationship. This is not enough to conclusively say that attachment is not important. Secondly, a full understanding of the relationship between attachment and all aspects of emotion understanding may have important implications for attachment theory. This includes thorough analysis of the differential effects for different types of emotional state, an aspect which Pavarini and colleagues (2012) did not address.

Reviews to date have taken a narrow approach to the definition of emotion understanding; for example, Pavarini and colleagues (2012) do not discuss studies investigating the relationship between attachment and emotion recognition. We would argue that the ability to *recognise* emotions is a key factor in being able to understand emotional states in others. Before one can understand why a person may be feeling a certain emotion, one first needs to recognise what the emotion is. Furthermore, according to belief-desire psychology, recognition of certain emotional states, such as surprise, requires knowledge of beliefs, and thus some level of Theory of Mind (e.g. Hadwin & Perner, 1991; Wellman & Banerjee, 1991; Wellman

& Bartsch, 1988). Thus, if attachment is related to only certain aspects of emotion understanding, we may expect differences in the relationship between attachment and different emotional expressions (those requiring knowledge of beliefs versus those requiring knowledge of desires).

Moreover, this may have implications for theories regarding the role of attachment in emotion understanding – Harris (1999) suggests that Laible and Thompson's (1998) findings provide evidence that attachment security is related to the ability to explore, rather than to recognise, emotions, as per Fonagy and Target (1997). Given that previous studies have found a discrepancy in the relationship between attachment and emotion recognition versus understanding the causes of emotions (e.g. Laible and Thompson, 1998), it seems pertinent to review whether research to date provides evidence for or against this view. Thus, papers investigating the relationship between attachment and emotion recognition are included in the present review.

The aims of the current review were therefore two-fold: 1) to comprehensively collate all papers investigating the relationship between attachment and emotion understanding, and 2) to better understand the relationship between attachment and the various facets of emotion understanding, including emotion recognition. Aim two subsumes a number of additional questions, as follows:

1. How has emotion understanding been measured in studies to date?
2. Is there a consistent relationship between attachment and emotion understanding?
3. If so, are there differences between different areas of emotion understanding (e.g. recognition, cognitive Theory of Mind and emotional Theory of Mind)?
4. Is attachment differentially related to different valences of emotions (positive or negative), which may provide evidence for competing hypotheses

regarding the nature of the relationship between attachment pattern and emotion understanding?

Methods

A search of the literature covering attachment and emotion understanding was conducted using PsycINFO and PubMed databases. Reference lists of retrieved articles were also manually searched for relevant publications. All papers investigating the relationship between attachment patterns and emotion understanding in typically developing children, up to and including age 12 years old were evaluated. In order to capture all relevant studies, and given the proposed association between cognitive Theory of Mind and emotion understanding (e.g. Harris et al., 1989), papers investigating emotion understanding, mentalisation, cognitive Theory of Mind (including false-belief) and emotion recognition were included within the search.

Inclusion and Exclusion Criteria

The search was limited to empirical papers published in English in peer reviewed journals up to 2012. Studies were included if they measured attachment and an aspect related to emotion understanding, including emotion recognition, cognitive Theory of Mind and emotional Theory of Mind. We included all study types, including cross-sectional and longitudinal, and those using only questionnaire measures as well as those using experimental paradigms. Only studies of typically developing children and in which attachment patterns were directly measured (through use of parent report, observation, structured or non-structured task) and reported were included. Thus, papers referring to ‘mother-child interaction’, or similar, but which did not report attachment pattern, were excluded from the search. Studies investigating emotion regulation were also excluded, as this relates to the

ability to regulate one's own emotions, and not the ability to understand the emotions of another (e.g. Southam-Gerow & Kendall, 2002).

The search strategy aimed to identify all research in which attachment was investigated alongside emotion understanding. The search terms were 'Attachment' along with Emotion* Understand*, Social Cognition, Theory of Mind, Affect Understand*, Affect Comprehen*, Emotion Recogni*, Mentalis*, Facial Expression, Emotion* Expression, Social Understand*, Understand* Feeling*, False*, False Belief, where * denotes truncated terms.

Search Results

The initial search strategy identified 221 papers. Following removal of duplicates, the titles, and, where necessary, abstracts, were read to identify studies broadly within the relevant area. Where titles and abstracts did not provide the required information, full papers were accessed for detailed review. The remaining papers were read in full and those meeting the search inclusion criteria were included in the formal review. Figure 2 illustrates the number of papers included at each stage of the review process, following the PRISMA (2009) Flow Diagram guidelines (Moher, Liberati, Tetzlaff & Altman, 2009).

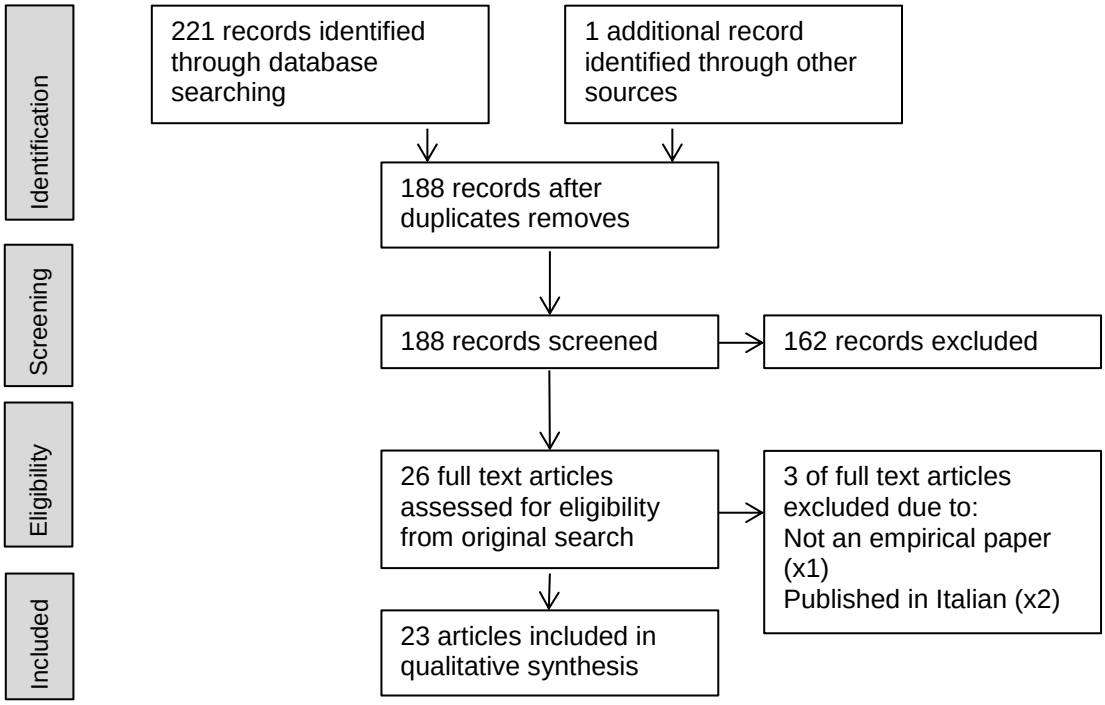

Figure 2. PRISMA (2009) flow diagram illustrating numbers of articles identified at each stage of the literature search.

Results

Twenty-three papers met the inclusion criteria and are included in the present review. Eleven were cross-sectional (Table 1) and twelve were longitudinal designs (Table 2). Of the longitudinal papers, 2 were follow-ups of the same cohorts of children (Raikes & Thompson, 2008 was a follow up study of the Raikes & Thompson, 2006 cohort and Steele, Steele & Croft, 2008 was a follow up of the Steele, Steele, Croft & Fonagy, 1999 cohort), giving a total of 21 independent studies. Tables 1 and 2 describe the sample characteristics of these studies.

Fourteen studies investigated white middle class populations, although a sizeable minority studied more disadvantaged groups. Notably, Barone and Lionetti (2011) studied a group of adopted children and Raikes and Thompson (2006, 2008) studied children who were enrolled in the US Early Head Start programme. This is a programme of services for children from low-income families. Arranz, Artamendi, Olabarrietta and Martin (2002) excluded children from high risk families. By design,

all studies assessed were English language; thus, unsurprisingly 18 studies took place in the UK, USA or Canada, with the remaining studying populations from Australia and Western Europe. A wide range of age groups of children were studied. The age of completion of emotion understanding tasks ranged from 26.4 months (Laranjo et al., 2010) to 132 months (Steele et al., 2008). Studies reported roughly equal male:female ratios.

Attachment measures

Eleven studies used assessments of attachment which provide categorical outcomes, and twelve used assessments which produce data on a continuum (Tables 3, 4, 5 & 6). Inter-rater reliability was generally good, with Cohen's κ figures ranging from around κ = 0.7 (e.g. Barone & Lionetti, 2011) to 1.0 (e.g. McQuaid et al., 2008). Only four studies (Arranz et al., 2002; De Rosnay & Harris, 2002; Laible & Thompson, 1998; Steele, Steele & Johansson, 2002) did not report inter-rater reliabilities for attachment assessments.

Continuum measures

Eight studies (Laranjo et al., 2010; Laible & Thompson, 1998; Ontai & Thompson, 2002; Ontai & Thompson, 2008; Raikes & Thompson, 2006; Raikes & Thompson, 2008; Symons & Clark, 2000; Waters et al., 2009) used versions of the Attachment Q-Sort (AQS; Waters & Deane, 1985) to record attachment patterns. This involves a rater coding parent-child interaction in observations of a number of different situations. The child is rated on a continuum for a number of attachment related behaviours, using cards which can be ranked in piles from 'most descriptive of the subject' to 'least descriptive of the subject'. The AQS Score is the correlation between this child and the prototypical 'secure' child. The observer report has good convergent validity with the Strange Situation (Van Ijzendoorn, Vereijken, Bakermans-Kranenburg & Riksen-Walraen, 2004). Van Ijzendoorn and colleagues'

(2004) meta-analysis suggested that the self (parent) - report version of the AQS is not a valid measure of attachment, however. Despite this, four studies have used this version (Ontai & Thompson, 2002; Laible & Thompson, 1998; Laranjo et al., 2010) and so the results of attachment security need to be treated with caution.

The AQS has a number of benefits; it can be carried out in the home and is therefore used in a naturalistic setting, which may produce more ecologically valid results and is less intrusive for the child and parent. It can also be used with a broader age range of children than the Strange Situation and is therefore useful for cross-sectional studies of older participants. However, a potential drawback is that it cannot be used to classify attachment types; it only rates children on a scale of security-insecurity. It was also not designed to assess disorganisation.

Table 1

Longitudinal Studies Investigating the Relationship between Attachment and Emotion Understanding in Children: Sample Characteristics

Paper	Type of Study	n (children)	Number of Males (% of n)	Mean Age (months)	Ethnic/Social Background	Country
Barone & Lionetti (2011)	Longitudinal	20	16 (75)	Time 1: 3.9 Time 2: 12-18 months post T1 Time 3: 12 months post T2	Children adopted between 36-60 months old	Italy
Laranjo, Bernier, Meins & Carlson (2010)	Longitudinal	61	25 (41)	Time 1: 12.9 Time 2: 15.6 Time 3: 26.4	Majority college degree and Caucasian	Canada
McElwain & Volling (2004)	Longitudinal	30	14 (47)	Time 1: 12 Time 2: 51	Predominantly Caucasian, mean 16.5 years maternal education At least 1 older sibling	USA
Meins, Fernyhough, Russell & Clark-Carter (1998)	Longitudinal	Time 1: 33 Time 2: 30 Time 3: 25 Time 4: 33	Time 1: 20 (61) Time 2: 20 (67) Time 3: 14 (56) Time 4: 20 (61)	Time 0: 11 or 13 Time 1: 31 Time 2: 37 Time 3: 49 Time 4: 61.5	Time 1: 13 group1. 20 group 2^{+} Time 2: 12 group 1, 18 group 2 Time 3: 8 group 1, 17 group 2 Time 4: 23 group 1, 20 group 2	UK
Meins, Fernyhough, Wainwright, Das Gupta, Fradley &Tuckey (2002)	Longitudinal	57	29 (51)	Time 1: 6 Time 2: 12 Time 3: 45.8 Time 4: 48.3	Predominantly white	UK
Ontai & Thompson (2002)	Longitudinal	Time 1: 52 Time 2: 29	Time 1: 25 (48) Time 2: 13 (45)	Time 1: 41.2 Time 2: 60.84	Predominantly European American, middle class	USA
Raikes &Thompson (2006)	Longitudinal	42	20 (48)	Time1: 28 Time 2: 42	Predominantly white working class (enrolled in Early Head Start)	USA
Raikes & Thompson (2008)	Longitudinal	42	20 (48)	Time 1: 28 Time 2: 42	Predominantly white working class (enrolled in Early Head Start)	USA

Steele, Steele & Croft (2008)	Longitudinal	Time 1,2,3: 96 Time 4: 63 Time 5: 49	Time 4: 34 (54) Time 5: 24	Time 1: pregnancy Time 2: 12 Time 3: 18 Time 4: 72 Time 5: 132	95% white middle class, 70% parental university degrees	UK
Steele, Steele, Croft & Fonagy (1999)	Longitudinal	63	29 (46)	Time 1: pregnancy Time 2: 12 Time 3: 18 Time 4: 70.7	95% white middle class, 70% parental university degrees	UK
Steele, Steele & Johansson (2002)	Longitudinal	Time 3: 51	Time 3: 25 (49)	Time 1: pregnancy Time 2: 12 Time 3: 18 Time 4: 136.8	Predominantly white middle class.	UK
Symons & Clark (2000)	Longitudinal	Time 1: 57 Time 2: 46	Time 2: 26 (56)	Time 1: 25.1 Time 2: 69.5	Wide range of SES, Blishen Score mean = 44.3*	Canada

* Blishen Score: socioeconomic index for occupations in Canada (Blishen, Carroll & Moore, 1987). The Blishen scale assigns SES codes to the occupations listed in the 1981 Canadian Classification and Dictionary of Occupations. At the time of the original scale, Over the 514 Census occupations, the index has a mean of 42.74, a standard deviation of 13.28, a minimum of 17.81, and a maximum of 101.74.

+ Measure of socioeconomic status in UK, as proposed by Mueller and Parcell (1981); Group1 = Unskilled/Manual workers, Group 2 = Professional workers

Table 2

Cross-sectional Studies Investigating the Relationship between Attachment and Emotion Understanding in Children: Sample Characteristics

Paper	Type of Study	n (children)	Number of Males (% of n)	Mean Age (months)	Ethnic/Social Background	Country
Arranz, Artamendi, Olabarrieta & Martine (2002)	Cross-sectional	114	54 (47)	44.6	Predominantly middle level of parental education	Spain
Colle & Del Giudice (2011)	Cross-sectional	122	51 (42)	86.4	Predominantly middle class	Italy
De Rosnay & Harris (2002)	Cross-sectional	51	25 (49)	60.9	Mixture of middle, lower- middle and working class families	UK
Fonagy, Redfern & Charman (1997)	Cross-sectional	77	33 (43)	58	Predominantly white working and lower middle class	UK
Greig & Howe (2001)	Cross-sectional	45	24 (53)	40	Predominantly white working class (26 group 1, 19 group 2^{+})	UK
Kidwell, Young, Hinkle, Ratliff, Marcum & Martin (2010)	Cross-sectional	54	31 (57)	54	Over 90% Caucasian. 56% receiving public assistance	USA
Laible & Thompson (1998)	Cross-sectional	40	20 (50)	50.4	Primarily middle class Caucasian	UK
McQuaid, Bigelow, McLaughlin & MacLean (2008)	Cross-sectional	33	19 (58)	57	All non-Hispanic white. Blishen Score mean 46.02*	Canada
Ontai &Thompson (2008)	Cross-sectional	78	36 (45)	53.76	Predominantly white middle class	USA

Repacholi &Trapolini (2004)	Cross-Sectional	48	24 (50)	53.98	Predominantly Caucasian middle class	Australia
Waters, Virmani, Thompson, Meyer, Raikes & Jochem (2009)	Cross-sectional	73	40 (55)	54.24	Ethnically and socioeconomically diverse	USA

* Blishen Score: socioeconomic index for occupations in Canada (Blishen, Carroll & Moore, 1987). The Blishen scale assigns SES codes to the occupations listed in the 1981 Canadian Classification and Dictionary of Occupations. At the time of the original scale, Over the 514 Census occupations, the index has a mean of 42.74, a standard deviation of 13.28, a minimum of 17.81, and a maximum of 101.74.

[+] Measure of socioeconomic status in UK, as proposed by Mueller and Parcell (1981); Group1 = Unskilled/Manual workers, Group 2 = Professional workers

Categorical measures

The Strange Situation (Ainsworth & Bell, 1970; Ainsworth et al., 1978), one of the most well-validated measures of attachment security, was also used in some studies. The original version is validated for children aged between 12 and 18 months and as such, was only used in longitudinal studies, where the attachment pattern was profiled some months/years before emotion understanding ability (Meins, Fernyhough, Russell & Clark-Carter, 1998; Meins et al., 2002; Steele et al., 1999, 2002, 2008). One study (Kidwell et al., 2010), used the Preschool Strange Situation (Cassidy & Marvin, 1992), which has been specifically developed for older children. McQuaid and colleagues (2008) used a non-validated videotape measure of mother-child reunions and separations, coded using the validated Crittenden's Preschool Assessment of Attachment (PAA) method (Crittenden, 1992). This involves classifying children into a broader range of attachment patterns than the traditional Ainsworth Strange Situation classificatory method. These measures have the advantage of being able to classify different attachment patterns, including assessment for disorganisation. However, despite good internal validity, these types of assessment may be distressing for mother and child, and if used within the laboratory, may have poorer ecological validity than the AQS.

A number also used narrative story stem techniques, which involve children completing an attachment themed story with dolls or pictures. The Attachment Story Completion Task (ASCT; Bretherton, Ridgeway & Cassidy, 1990), Manchester Child Attachment Story Task (MCAST; Green, Stanley, Smith & Goldwyn, 2000) and Separation Anxiety Test (SAT; Klagsbrun & Bowlby, 1976) were used, which are all validated measures of attachment (e.g. Bretherton et al., 1990; Goldwyn, Stanley, Smith & Green, 2000; Shouldice & Stevenson-Hinde, 1992).

One difficulty with using such assessment types within studies of emotion understanding is that they require some degree of Theory of Mind, as the child is

expected to ‘pretend’ to be a character within the stories, or to imagine what characters would think, feel or do. There would therefore arguably be a degree of overlap within performance on these tests and performance on tasks of emotion understanding. Children may also perform better on these assessments if they understand emotions better, and thus this may confound their use within research assessing emotion understanding. However, they are usually not ‘marked’ in the same way as tests of emotion comprehension – the information generated is more qualitative in nature. Never-the-less, it may be assumed that a child who struggles with Theory of Mind, or understanding of emotion, may struggle to generate material for attachment themed stories, regardless of their attachment status.

Of those studies using categorical assessments of attachment pattern, most found a majority of secure attachment patterns, which is consistent with the populations studied. A small minority of children showed disorganised attachment patterns. Steele and colleagues (1999) re-classified disorganised children into other attachment groups for the purposes of analysis, and McElwain and Volling (2004) did not assess for disorganisation as they state that the disorganised category was not used consistently at the time their data was collected. There is therefore limited potential for assessing whether disorganisation has a role to play in the association of attachment with emotion understanding. One study (De Rosnay & Harris, 2002) did not report attachment patterns for the whole sample, instead splitting them for children who did and did not pass various emotion understanding tasks. In all but three (McElwain & Volling, 2004; Steele et al., 1999; Steele et al., 2002) of the studies, the primary care-giver assessed was the mother; investigation of father-infant attachment is limited (as in other areas of attachment research), and this is a potential avenue for future studies to explore.

The relationship between attachment and emotion understanding

For the purposes of this review, the tasks have been split into three main areas: pure emotion recognition tasks, cognitive Theory of Mind tasks and emotional Theory of Mind tasks. Some studies did not fit into these discrete categories. We have termed these studies 'mixed mind and emotion'. Only three studies (Repacholi & Trapolini, 2004; McQuaid et al., 2008; Meins et al., 1998) explicitly mentioned that the emotion understanding task was scored by a researcher blind to the child's attachment status, all of which found some effect of attachment on emotion understanding. Of the 6 out of 21 studies reporting inter-rater reliability for emotion understanding/Theory of Mind tasks (Colle & Del Giudice, 2011; Kidwell et al., 2010; Laible & Thompson, 1998; McQuaid et al., 2008; Meins et al., 2002; Repacholi & Trapolini, 2004), reliability was acceptable.

Emotion recognition tasks

Two studies used tasks of pure emotion recognition (Table 3); both used tasks developed specifically for the research in question and report good inter-rater reliabilities. Steele and colleagues (2008) conducted a longitudinal study in which attachment was assessed using the Strange Situation (Ainsworth et al., 1978) when the infant was 12 months old, and emotion understanding was measured at 6 and 11 years. They used an emotion judgement task in which children were shown nine simplified line drawings of facial expressions – six basic expressions (fear, anger, sadness, disgust, happiness, surprise) and two expressions of complex or mixed emotions (mischief and disappointment). At 6-years-old, participants were asked to say one or more words to describe the face. At 11-years-old, they were asked to write down a word or phrase that described the face. Responses were coded as correct or incorrect, and a total accuracy score for responses across all nine faces was calculated. Descriptions were audio-recorded and transcribed. Results

demonstrated that children with insecure infant-mother attachments, although not disorganised attachment patterns, performed worse on the task of verbal emotion labelling. The effect was stronger at age 6 than at age 11 years, and was statistically significant only at 6 years old. Interestingly, insecure children were particularly poor at identifying positive emotions. Infant-father attachment measured at 18 months was not related to performance.

Colle and Del Giudice (2011) were the only researchers to investigate recognition of moving rather than static facial expressions. Two tasks of emotion recognition were given, each made up of 14 items (10 negative emotions and 4 positive). The researchers aimed to separate out verbal and non-verbal aspects of emotion recognition. Thus the first task was non-verbal discrimination. The child was shown a video clip in the middle and four around the periphery of the screen. They were asked to find the person in the periphery who feels the same as the one in the centre. The second task was emotion labelling; the child was simply asked 'how do you think this person is feeling'. It could be argued that this is a more naturalistic task than that of Steele and colleagues (2008), as it used moving images of real people, as opposed to simplified cartoon images. Attachment was measured concurrently, using the Manchester Child Attachment Story Task (MCAST; Goldwyn et al., 2000; Green et al., 2000). The researchers found no effect of concurrent attachment on the verbal emotion description (labelling) task, however there was an effect of attachment on the non-verbal emotion discrimination task, both assessed at 7-years-old (disorganised children scored lower than the other attachment groups). This may be because the average age of these children was slightly older, given that the results from the Steele and colleagues (2008) study were only significant for children age 6, and not at age 11.

Table 3

Articles Investigating the Relationship between Attachment and Emotion Recognition in Children

Paper	Attachment Measure (age in months)	Number of Securely and insecurely Attached Children (Secure %, Insecure %, Disorganised % for categorical)	Emotion Understanding Measure (age in months)	Significant Relationship between Attachment and Emotion Understanding?	Other Key Variables Associated with Emotion Understanding
Colle & Del Giudice (2011)	Manchester Child Attachment Story task (MCAST; Goldwyn, et al., 2000; Green et al., 2000) (84)	54, 30, 16	Non-verbal discrimination task Emotional labelling task (84)	Yes (non-verbal task) No (verbal task)	Gender (girls > boys)
Steele, Steele & Croft (2008)	Strange Situation at 12 months	6 year follow up: 57, 35, 8 11 year follow up: 58, 36, 8	Emotion Judgement Task at 6 and 11 years	Yes at 6 years, trend level at 11 years	Gender (girls > boys) (Parental and child verbal abilities, and father-infant attachment not associated)

Cognitive Theory of Mind tasks:

Although a number of studies investigated Theory of Mind, fewer used tasks that did not contain an emotional component (Table 4). Cognitive Theory of Mind tasks have generally been shown to have good reliability across a wide range of ages (e.g. Hughes et al., 2000). Three studies (Greig and Howe, 2001; Meins et al., 2002; Repacholi and Trapolini, 2004) used versions of a standard false-belief task developed by Perner, Leekam, and Wimmer (1987) known as 'the Smartie Task', in which the child is shown a Smartie Tube and then sees that it is filled with pencils, rather than chocolate. The child is then asked where a character will look for the Smarties and whether they are really there or not.

Tasks of unexpected identity (where an item looks like something else) were also used (Meins et al., 1998, 2002; Repacholi and Trapolini, 2004). In addition, McElwain and Volling (2004) and Meins and colleagues (1998, 2002) used tasks of unexpected transfer, in which an object is moved out of sight of a character, and the character comes back to look for it. Laranjo and colleagues (2010) used the 'Discrepant Desires' task (Repacholi & Gopnik, 1997), which involved the child needing to give the experimenter (i.e. a stranger) a book to read; it required the child to understand that the experimenter wanted to read a different book than they would want to read themselves. They also used the 'Visual Perspectives' task, which required the child to understand what his/her *mother* could see in order to show them a toy.

McElwain and Volling (2004) and Meins and colleagues (1998) found performance on an unexpected transfer task at age four was significantly better in children with secure attachments, assessed using the Strange Situation (Ainsworth et al., 1978) at one year. Maternal sensitivity (McElwain & Volling, 2004; Meins et al., 1998) and mothers' tendency to describe their child in terms of their 'mental' attributes (e.g. 'caring'; Meins et al., 1998) were also significantly related to performance, as well as to attachment status. Meins and colleagues (1998) did not

find significant difference between attachment groups on a false-belief task at age five, however.

Repacholi and Trapolini (2004) found that the concurrent attachment dimension of the self-Separation Anxiety Test - Seattle Version (self-SAT; Klagsbrun & Bowlby, 1976; Slough & Greenberg, 1990) was positively correlated with false-belief score (both assessed at 4 years old), even when age and gender were controlled for. Age and language were also both significant independent predictors. Greater differences between different attachment patterns were seen for the task involving an attachment figure (visual perspectives) compared to the task involving a stranger (discrepant desires).

Repacholi and Trapolini (2004) also investigated children's understanding of the causes of emotions. Interestingly, scores on the Theory of Mind and 'pure' emotion understanding tasks were not significantly correlated. The emotion task used was a modified 'causes of emotions' interview (Dunn & Hughes, 1998), in which children were asked to identify the expression and possible antecedents of this for four child's faces, four mother's faces and four unknown female's faces. Children were most competent at explaining causes of their own emotions, followed by their mother's, and least competent in explaining the stranger's emotion. Results demonstrated that the attachment dimension of the SAT was a significant independent predictor of performance on the emotion understanding task. Unlike the Theory of Mind task, there was no relationship between attachment security and differential performance for identifying the emotions of different people.

Laranjo and colleagues (2010) also found a small (but non-significant) longitudinal effect of attachment security (assessed with the Observer Attachment Q-Sort; AQS, Waters & Deane, 1985) at 15.6 months, on their task involving the mother's perspective (visual perspective task; assessed 10 months later), once children's expressive language was controlled for. There was no effect for the Discrepant Desires task, involving a stranger, however. When the genders were

separated, there was a significant effect of attachment on the visual perspective task for boys, but not girls, with more securely attached boys performing better on this task. Maternal mind-mindedness (in particular, mothers' references to desires) was related to performance in both tasks for the whole sample. However, the effects of mind-mindedness and attachment on performance were not considered together within one analysis, and thus it is difficult to conclude whether attachment would still have been a significant predictor had mind-mindedness been controlled for.

Similarly, Meins and colleagues (2002) found that mothers' appropriate mental state comments (assessed when the child was 6 months old), and child verbal abilities (assessed at 45 months), but not attachment status (assessed using the Strange Situation at 12 months old), were related to performance on Theory of Mind tasks at 45 months old. Greig and Howe (2001) also found no relationship when attachment (assessed with the Attachment Story Completion task; Bretherton et al., 1990) and false-belief understanding were assessed concurrently at 3 years old. Repacholi and Trapolini (2004) stated that this may be because Greig and Howe (2001) tested younger children, who are 'more likely to either consistently fail the false-belief or to perform at chance levels'.

Arranz and colleagues (2002) found that performance on a false-belief task at 3 to 4 years old was significantly associated with attachment assessed concurrently with the Spanish version of the Attachment Story Completion task (Bretherton et al., 1990), with more secure children performing better.

Table 4

Articles Investigating the Relationship between Attachment and Cognitive Theory of Mind in Children

Paper	Attachment Measure (age in months)	Number of Securely and Insecurely Attached Children (Secure %, Insecure %, Disorganised % for Categorical)	Emotion Understanding Measure (age in months)	Significant Relationship between Attachment and Emotion Understanding?	Other Key Variables Associated with Emotion Understanding
Arranz, Artamendi, Olabarrieta & Martine (2002)	Attachment Story Completion (Bretherton et al., 1990) (Spanish Version) (44.6)	56.1, 32.5 missing cases - 11.4%	False-belief Tasks: Wellman's belief-desire psychology (44.6) Max and the chocolate task (Wimmer & Perner, 1983) (44.6)	Yes	No relation to family size or number of siblings
Greig & Howe (2001)	Attachment Story Completion (Bretherton et al., 1990) (40)	45, 36, 18	Emotion Understanding Task (Denham & Auerbach, 1995) False-belief Task (Bartsch and Wellman, 1989) (40)	Yes for emotion task No for false-belief task	Maternal depression Child verbal mental age
Laranjo, Bernier, Meins & Carlson (2010)	Observer Attachment Q-Sort (15.6)	M=.47 SD =.25 Range -.28 - .82	Discrepant desires (adapted from Repacholi & Gopnik, 1997) (26) Visual perspectives (Carlson et al., 2004) (26)	No. Marginal trend for visual perspectives after control for expressive language	Maternal mind-mindedness Unrelated to maternal education, older sibs, gender, age, language
McElwain & Volling (2004)	Strange Situation (Ainsworth et al.. 1978), assessed on a continuous scale as per Main, Kaplan & Cassidy (1985) (12)	Mothers:19, 11 Fathers: 17, 13 disorganised not used	False-belief: two trials of the 'Sally-Ann' task (Baron-Cohen, Leslie & Frith, 1985) (51)	Yes (but only marginally significant if sex added as a covariate)	Parental sensitivity (but only marginally significant if sex added as a covariate). Main effects of parent (mother/Father) and sex not significant
Meins, Fernyhough, Russell & Clark-Carter (1998)	Strange Situation (Ainsworth et al., 1978) (11 or 13)	T1: 58, 30, 12 T2: 57, 43 T3: 60, 40 T4: 58,30,12	Unexpected Transfer Task (Wimmer & Perner, 1983) at 4 years (T3) Picture identification task & False-belief and emotion task at 5 years (T4)	Yes at 4 years Yes for picture identification task at 5 years No for false-belief and emotion task at 5 years	Child executive capacity(T1) Maternal tutoring sensitivity (T2) Maternal focus on mental description of children (T2)

Meins, Fernyhough, Wainwright, Das Gupta , Fradley &Tuckey (2002)	Strange Situation (Ainsworth, 1978) (12)	67, 26, 7	The appearance-reality task (Flavell, Flavell & Green, 1983) - 45 months The deceptive box task (Hogrefe, Wimmer & Perner, 1986) - 45 months Unexpected transfer task at 48 months Combined composite measure of ToM	No	Maternal sensitivity and mind-mindedness (number of appropriate mind related comments) at 6 months and Child verbal mental age Not related to number of older sibs or mothers inappropriate mind related comments
Repacholi &Trapolini (2004)	Separation Anxiety Test (Klagsbrun & Bowlby, 1976) Seattle Version (Slough & Greenberg, 1990) (53.98)	Summary scores for each SAT dimension sig correlated for self and other child therefore only SAT self scores presented.	2 modified false-belief tasks - unexpected contents &unexpected identity involving mother 2 standard false-belief tasks - unexpected contents (Smarties; Perner et al, 1987), unexpected identity (peep-hole book; Gopnik & Astington, 1988) 'Causes of emotions' interview (Dunn & Hughes, 1998) involving mother (53.98)	Yes	Age and language related to total false-belief score

Emotion understanding/Emotional Theory of Mind tasks

Summaries of studies investigating emotion understanding/emotional Theory of Mind tasks are detailed in Table 5.

Denham's Affective Perspective Taking Task

Five studies (Greig & Howe, 2001; Laible & Thompson, 1998; Ontai & Thompson, 2002; Raikes & Thompson, 2006, 2008; Waters et al., 2009) used Denham's affective perspective-taking task (Denham, 1986), which Denham (2006) cites as having excellent inter-rater reliability and validity. This firstly involves an emotion recognition task (showing a puppet with an emotional expression and asking how the puppet feels), and then involves identification of the puppet's feelings in a number of vignettes (usually eight). Four main categories of emotion are used; happy, sad, afraid and angry; two vignettes are used for each emotion and each vignette is scored out of 2 (where 0 is wrong, 1 is correct valence, i.e. picking a correctly positive or negative emotion, and 2 is for correct emotion). Thus the maximum possible score is usually 16. In one study (Waters et al. 2009), this task was scored only for the understanding of negative emotions. Although this task clearly relates to emotion recognition, scores are based on identification of how the puppet feels in relation to the vignettes (i.e. only the emotion understanding component is scored). Children are usually 'trained' to recognise the emotional expression of the puppet, and thus pure emotion recognition abilities should be controlled for.

Three studies using Denham's emotion understanding task (Greig & Howe, 2001; Laible and Thompson, 1998; Raikes and Thompson, 2006, 2008) found a significant relationship between performance on this task at 3 to 4 years old, and attachment, with more secure children performing better. This was true when attachment was measured concurrently at three to four years, with Bretherton and colleagues' (1990) Attachment Story Completion task (Greig & Howe, 2001), and

with the AQS (Laible & Thompson, 1998). The same effect was found when attachment had been assessed with the AQS over one year earlier (Raikes & Thompson, 2006, 2008). When emotional valences were separated, only age proved to be a significant independent predictor for positive emotions, but both age and attachment were significant independent predictors in understanding negative emotions, with more securely attached children better at understanding negative emotions (Laible & Thompson, 1998). However, Raikes and Thompson (2008) found that once mother-child references to emotion in a semi-structured interview were included in the model, attachment security was no longer a significant independent predictor; the effects of security on emotion understanding were mediated through mother-child references to emotion.

In contrast to these results, two studies (Ontai & Thompson, 2002; Waters et al., 2009) found no effect of concurrent attachment pattern assessed with the AQS on performance on Denham's task, assessed at 3 to 4 years old. Gender and maternal discourse style; pragmatism (i.e. confirmations that the child's emotion-related talk is right, directions about the 'proper' way to respond to an emotion, negation/correction of the child's incorrect emotion-related statement, and repetition of the child's emotion-related talk) and elaboration (i.e. discussion about: the causes of the emotions, linking the emotion to events in the child's life, requests for emotion-related information and the behavioural results of emotions) were related, however (Ontai & Thompson, 2002). Girls, and children with mothers who used pragmatic discourse, tended to have higher negative emotion understanding scores (although this relationship was only marginally significant).

The lack of a significant association between attachment and emotion understanding may be due to the age of participants; children were younger than in many studies and at an age where emotion understanding is just developing (Ontai & Thompson, 2002). However, at 5 years old, concurrent attachment status *was* a significant predictor of emotion understanding, with more securely attached children

having higher total emotion understanding scores and negative emotion understanding scores (Ontai & Thompson, 2002). Age, gender and attachment at 41 months were not significant predictors of emotion understanding at 61 months, however.

An interaction term between attachment at 41 months and elaborative style accounted for a significant amount of additional variance in positive emotion understanding at 61 months. For children with less secure attachments, higher elaborative discourse style was linked to lower positive emotion understanding scores at 61 months. Conversely, for children with more secure attachment styles, high elaborative discourse style was linked to better understanding of positive emotions at 61 months.

Conversational tasks

Consistent with Ontai & Thompson's (2002) results, maternal use of language was also found to be important in other tests of emotion understanding. McQuaid and colleagues (2008) assessed the number of appropriate mental state comments that 3- to 6-year-old children made when in conversation with their mother. The task was novel, but results demonstrated good inter-rater reliability. Mothers' mental state language and the child's attachment status, using observations of mother-child separations and reunions, and measured concurrently with emotion understanding, were both associated with the amount of mental state talk the child engaged in. However, only maternal mental state language was significantly associated with children's expressions of emotion understanding, scored as comments made in reference to an emotional state and explanation for that state.

The two studies which rated emotion understanding from conversations with the experimenter (Kidwell et al., 2010; Laible & Thompson, 1998) both found emotion understanding to be significantly associated with concurrent attachment status, at approximately 4 years old, with more securely attached children

performing better. Kidwell and colleagues (2010) found that for both positive and negative emotion understanding, children classified as having an insecure-resistant attachment relationship, assessed with the Strange Situation (Ainsworth et al., 1978) displayed less emotional competence than securely attached children, when controlling for verbal ability and socioeconomic risk. As previously described, Laible and Thompson (1998) summed the score on the affective perspective taking task and interviews into one score of emotion understanding.

Modified false-belief tasks

Modified false-belief tasks involving emotions were used in two studies (De Rosnay and Harris, 2002; Fonagy et al., 1997). De Rosnay and Harris (2002) used the 'Dog-Rabbit Test', in which children were asked to describe the emotional state (happy or sad) of the character in response to a scenario, and explain why they were feeling that way. They also used a novel analogue to the Dog-Rabbit test, which they named the 'Mother-Infant Separation Test', which involved an attachment figure. Fonagy and colleagues (1997) used the 'Ellie-the-elephant/Coke-can belief-desire reasoning task' (Harris, Johnson, Hutton, Andrews & Cooke, 1989), in which children were asked to make and justify two predictions about emotion. The task is similar to a task of false-belief, in that a character (Ellie) leaves her favourite drink (coke) out and goes for a walk. Her friend Mickey then plays a trick on her, by replacing the coke in the coke-can with milk. The child is then asked how Ellie feels when she first looks at the coke-can, and then how she feels after she drinks from the can. The child is also asked to explain *why* Ellie feels that way. Interestingly, Repacholi and Trapolini (2004) also gave children this task, but as 81% of their sample of 4-year-olds failed the task, they did not include the results within their analysis.

Both studies (De Rosnay & Harris, 2002; Fonagy et al., 1997) found that concurrent attachment, and more specifically, the attachment dimension of the SAT,

was a significant independent predictor of performance in children between 3 and 5 years old.

Character/Cartoon-based tasks

Four papers used tasks involving identifying the emotions and causes of emotions of a character (Barone & Lionetti, 2011; Repacholi & Trapolini, 2004 – discussed in cognitive Theory of Mind section; Steele et al., 1999, 2002). Steele and colleagues (1999, 2002) asked children to identify the emotions of a set of line drawings and then choose the appropriate expression to go in a blank face of a character in various attachment-related situations ('acknowledgement of distress'). The children were also prompted for possible mixed emotions.

Steele and colleagues (1999) found that mother-infant attachment pattern, assessed with the Strange Situation at 12 months, was significantly positively correlated with mixed-emotion understanding at 6 years, but the father-infant attachment pattern (also assessed with the Strange Situation) at 18 months was not significantly correlated with emotion understanding. Prenatal maternal adult attachment security (i.e the attachment pattern of the mother, assessed prior to the birth of her baby, measured with the Adult Attachment Interview; AAI; George, Kaplan & Main, 1985) was also significantly correlated with understanding of mixed emotions at 6 years old, with more secure mothers associated with better child performance on the emotion understanding task. In a regression model involving the child's age, dichotomised mother-infant attachment status and parental adult attachment status, only infant-mother attachment was found to be a significant independent predictor of emotion understanding (potentially because maternal AAI is highly correlated with infant-mother attachment). Conversely, Steele and colleagues (2002) found no significant associations between infant-mother attachment security at 12 months or infant-father attachment at 18 months, and 11-year-olds' ability to acknowledge distress in their emotion understanding task.

Maternal AAI security during pregnancy and maternal self-reports of nurturance were correlated with these abilities, however.

Barone & Lionetti (2011) used a validated Italian version of the 'Test of Emotion Comprehension (TEC; Pons & Harris, 2000; validated by Albanese & Molina, 2008). Similarly to the tasks described previously, the child is shown a picture book with cartoon scenarios, facial expressions and stories about emotions. The child is scored on recognition of the facial expression, understanding the external causes of emotions, understanding the possibility of regulating emotions, and understanding the ability to hide an emotional state. In a group of 3- to 5-year-old adopted children, those with disorganised attachment patterns, assessed using the Manchester Child Attachment Story Task (MCASR; Goldwyn et al., 2000; Green et al., 2000), were found to have significantly worse performance on the task of emotion understanding (assessed 12 months following attachment assessment) than children with other attachment patterns (Barone & Lionetti, 2011). Within organised attachment patterns, there were no significant differences between securely and insecurely attached children. However, as this task includes aspects of emotion regulation, it may be that attachment status related to this rather than emotion understanding per se. Thus, we cannot conclude that there is an effect of attachment on emotion understanding for this task.

Table 5

Articles Investigating the Relationship between Attachment and Emotional Theory of Mind Tasks

Paper	Attachment Measure (age in months)	Number of Securely and Insecurely Attached Children (Secure %, Insecure %, Disorganised % for Categorical)	Emotion Understanding Measure (age in months)	Significant Relationship between Attachment and Emotion Understanding?	Other Key Variables Associated with Emotion Understanding
Barone & Lionetti (2011)	Manchester Child Attachment Story Task (MCASR; Goldwyn, Stanley, Smith & Green, 2000; Green, Stanley, Smith and Goldwyn, 2000) (12-18m post adoption at 3.9 years)	25, 40, 16	Test of Emotion Comprehension (TEC; Pons & Harris, 2000) (12 months after MCASR)	Yes	Adopted children < normative sample
De Rosnay & Harris (2002)	The Separation Anxiety Test (Klagsbrun & Bowlby, 1976) (60.9)	Not reported for total sample	False-belief Tasks: The Dog-Rabbit Test - Mother-Infant Separation Test - novel analogue to Dog-Rabbit Test. Low and high expressed emotion versions (60.9)	Yes	Verbal Mental Age (older>younger) Chronological age (older>younger)
Fonagy, Redfern & Charman (1997)	The Separation Anxiety Test (Klagsbrun & Bowlby, 1976) (58)	For attachment dimension score alone - 31.6, 18.4% 38 & 50% ambiguous	Ellie the elephant belief-desire reasoning (Harris et al., 1989) (58)	Yes	Chronological age Verbal mental age (both older>younger) although both NS once account for attachment
Kidwell, Young, Hinkle, Ratliff, Marcum & Martin (2010)	Strange Situation (Ainsworth, 1978), coded using Crittenden's PAA method (54)	30, 70	Emotional competence - Abner Emotions Interview (54)	Yes	Receptive Vocabulary
Laible & Thompson (1998)	Attachment Q-Sort Version 3.0 (Waters & Deane, 1985) (50.4)	Continuous Scores for attachment security. Mean = 0.48, SD = 0.15, range = .15 - .71	Affective perspective-taking task (Denham, 1986) (50.4) Interview - Fabes et al. (1988) (50.4)	Yes - total and negative emotion understanding	Age (older>younger) Not gender

McQuaid, Bigelow, McLaughlin & MacLean (2008)	Videotapes of two-mother child reunions and two mother-child separations coded using Crittenden's PAA method (57)	58,44	Child participates in scenarios adapted from Geneva emotion eliciting scenario (Favez et al., 1994) (57) Co-construction narrative with mother Consolidation narrative with experimenter	Yes for co-construction, although effect smaller once account for maternal comments on mental state No for consolidation	Maternal comments on mental state
Ontai & Thompson (2002)	Attachment Q-Sort Version 3.0 (Waters & Deane, 1985) (41.2 & 60.84)	Continuous Scores for attachment security. Mean = 0.43, SD = 0.19, range = .02 -.90 (41.2) Mean = .37, SD = .17 (60.84)	Denham (1986) Puppet task (41.2 & 60.84)	No at 41.2 months Yes at 60.84 months (only attachment at 60.84 months related, not attachment at 41.2 months)	Gender (Girls > boys) Maternal pragmatic discourse (41.2) Interaction elaborative discourse and attachment (60.84)
Raikes &Thompson (2006) & Raikes & Thompson (2008)	Attachment Q-Sort (Waters and Deane, 1985) (28)	Continuous Scores for attachment security. Mean = 0.22, SD = 0.25, range = -.21 - .75	Denham's affective perspective-taking task (Denham, 1986) (42) Videotape and mother and child discussing several emotional events in the recent past (modification of Fivush,1991) (42)	Yes for labelling of emotional states Yes for emotion understanding (although not after controlling for mother-child references to emotion)	Maternal depression (at 28m but not 42m) Child receptive vocabulary Mother-child references to emotion
Steele, Steele, Croft & Fonagy (1999)	Strange Situation Mother (12) Father (18)	Mother: 57, 33, 10 Father: 75, 25 Disorganised reclassified due to small numbers	The Affect Task - assessing understanding of mixed emotions (70.7)	Yes (Mother-infant), No Father-infant)	
Steele, Steele & Johansson (2002)	Strange Situation Mother (12) Father (18)	Mother: 37, 55, 8 Father: 32, 66, 2	Modified version of 'Affect Task' above (136.8)	No	Maternal AAI at pregnancy
Waters, Virmani, Thompson, Meyer, Raikes & Jochem (2009)	Attachment Q-Sort Version 3.0 (Waters & Deane, 1985) (54.24)	Mean = .37, SD = .18, range = -.08 - .68	Denham's affective perspective-taking task (Denham, 1986). Scored only for negative emotion understanding (54.24)	No	Child avoidance of conversation about negative experiences

Mixed mind and emotion

Two studies (Ontai & Thompson, 2008; Symons & Clark, 2000) used tasks which involved a combination of 'mind' and 'emotion' tasks (Table 6).

Ontai & Thompson (2008) used a combination of a standard unexpected location task (Wimmer & Perner, 1983), emotion attribution task (Harris et al., 1989), unexpected location task involving the mother and emotion attribution task involving the mother. In this study, all of the tasks were combined to create a Theory of Mind summary score. Theory of Mind abilities and attachment security (assessed with the AQS) were investigated concurrently at 4 years old. Mother-child elaborative discourse and mother-child mental state discourse were also assessed. Only elaborative discourse proved to be a significant independent predictor of children's Theory of Mind scores. Attachment was neither a significant independent predictor of, nor correlated with, Theory of Mind.

Symons and Clark (2000) gave children three sets of false-belief tasks, involving the identity and location of objects and locations of caregivers. In each case, both false-belief and emotional justification questions were asked. The authors did not find a significant correlation between attachment security (assessed with the AQS) and performance on the caregiver location task. They did, however, find a positive correlation between performance on the object location task and concurrent attachment security (at 5 years old), but not with attachment security at 2 years old. Neither age 2, nor age 5 attachment security predicted variance in scores on the caregiver location task. However, maternal sensitivity and maternal emotional distress were significant independent predictors. Children with more sensitive mothers, and, interestingly, mothers who were in greater emotional distress when children were 2 years old, performed better on the caregiver location task at 5 years old.

Table 6

Articles Investigating the Relationship between Attachment and Mixed Cognitive and Emotional Theory of Mind Tasks

Paper	Attachment Measure (age in months)	Number of Securely and Insecurely Attached Children (Secure %, Insecure %, Disorganised % for Categorical)	Emotion Understanding Measure (age in months)	Significant Relationship between Attachment and Emotion Understanding?	Other Key Variables Associated with Emotion Understanding (age in months)
Ontai &Thompson (2008)	Attachment Q-Sort Version 3.0 (Waters & Deane, 1985) (41.2)	Continuous Scores for attachment security. Mean = 0.43, SD = 0.19, range = .02 -.90	Standard unexpected location task (Wimmer & Perner, 1983) Emotion attribution task (Harris et al, 1989) Unexpected location task involving mother Emotion attribution task involving mother	Yes, for negative emotions at 5 years No at 3 years.	Gender girls >boys Maternal use of elaborative and pragmatic discourse
Symons & Clark (2000)	Attachment Q-Sort (Waters, 1987; Waters et al, 1995) (25.1 & 69.5)	69.5: Mean = .5, SD = .23, range = -0.15 - .93) 25.1: Mean = .42, SD = .27, Range = -.13 - 1.07	False-belief Tasks (69.5) 3 sets investigating: 1) Object identity 2) Object location x 2 - from Wimmer and Perner (1983) unexpected transfer task. 3) Caregiver location x 3 (modelled after object location)	Yes (object location at 69.5)	Maternal sensitivity (25.1) No relation to number of siblings

Discussion

Summary of findings

Seventeen out of twenty-one independent studies reported an effect of attachment status on emotion understanding. In general, insecure infant-mother or child-mother attachment was linked to poorer performance on emotion understanding tasks. This review therefore provides evidence for the Attachment Status Model of the development of emotion understanding, as discussed by Harris (1999). However, four studies did not find any effect of attachment on emotion understanding, once other variables were controlled for (Laranjo et al., 2010; Meins et al., 2002; Steele et al., 2002; Waters et al., 2009). Additionally, studies differed in the extent to which other variables (such as maternal discourse) moderated or mediated the effect. Markedly differing methodologies limit the interpretation of findings. For example, studies diverged in attachment measures, emotion understanding measures, sample population and ages of children tested. Previous research has demonstrated that all of these factors can affect outcomes in attachment studies (see Schneider, Atksinson & Tardif, 2001).

Schneider and colleagues (2001) consider that findings from longitudinal studies, spanning developmental stages "provide more convincing support" (p. 89) than do concurrent correlations. Of the studies which investigated attachment at more than one time point, in some, concurrent attachment demonstrated a stronger relationship with emotion understanding than did earlier attachment status (Ontai & Thompson, 2002; Symons & Clark, 2000). When early attachment status has been associated with emotion understanding at more than one time point, Steele and colleagues (2008) found that early attachment was associated with emotion understanding at 6 years but not at 11. However, contrary to this, Ontai and Thompson (2008) found that attachment status at 41 months was not associated with emotion understanding at 41 months, but was related to the understanding of negative emotions at 5 years. Thus, generally, the closer together in time that

attachment and emotion understanding are measured, the stronger the relationship between the two, although there are exceptions. This is in line with proposals that the relationship between attachment and other outcomes may be strongest when attachment patterns are measured concurrently with the outcome of interest, rather than longitudinally (e.g. Youngblade, Park & Belsky, 2003).

Where studies separated out performance for positive and negative emotions (e.g. Laible & Thompson, 1998; Ontai & Thompson, 2008), some demonstrated associations between attachment and negative emotions, some with positive and some both. Most studies did not separate out positive and negative emotions and therefore it is difficult to disentangle the competing 'hypervigilance hypothesis' (e.g. Belsky et al. 1996) from the 'diminished lexicon for emotion hypothesis' (e.g. Steele et al., 2008). Of course, as noted by Steele and colleagues (2008), the hypotheses may not be contradictory; insecure attachment patterns may be linked to a diminished lexicon for emotion, whereas disorganised attachment patterns may be linked to hyper-vigilance for negative emotion. As many studies used the Attachment Q-Sort (Waters & Deane, 1985), which does not separate attachment patterns, this is also difficult to evidence at present.

In their 2004 article, Repacholi and Trapolini stated that "whereas the findings have been mixed with regards to false-beliefs, the evidence is more compelling for a link between attachment and emotion understanding" (p. 399). The evidence nine years later looks broadly similar, with tasks of emotional Theory of Mind being more often associated with attachment, in comparison to tasks of cognitive Theory of Mind. However, few studies looked at both emotion understanding and cognitive Theory of Mind within the same study. Those that did, found conflicting results. For example, Greig and Howe (2001) found a significant relationship between attachment and emotion understanding, but not attachment and cognitive Theory of Mind. Conversely, Repacholi & Trapolini (2004) found

significant relationships for both emotion understanding and cognitive Theory of Mind. Greig & Howe (2001) comment that "studies on children's social understanding tend to assume that understanding the minds and emotions of others are theoretically and methodologically indistinct" (p. 381). Our results would suggest that future research should consider these to be separable abilities. More studies are needed that investigate both cognitive and emotional Theory of Mind within the same study (and thus the same sample), to determine whether these aspects do relate to attachment differently.

Limitations

i. Attachment measures

Some studies used attachment measures which we may assume require some level of emotion understanding. Interestingly, within studies using story-stem assessments of attachment, null findings were found for tasks of emotion recognition (Colle & Del Giudice, 2011) and cognitive Theory of Mind (false-belief; Greig & Howe, 2001), and not for tasks of 'pure' emotion understanding/emotional Theory of Mind. Perhaps, therefore, studies using story completion tasks and emotional Theory of Mind tasks (Arranz et al., 2002; Barone & Lionetti; Greig & Howe, 2001) were confounded. We would recommend that these results are thus treated with caution, and that future studies assessing the relationship between attachment status and emotion understanding avoid using story completion assessments of attachment.

Further to issues of attachment measurement, Fraley and Waller (1998) explain that the various measures have differing reliability and validity. In particular, attachment categories have been shown to have moderate, but not perfect, stability across time (correlation coefficient = 0.39; Fraley, 2002). According to Fraley and Waller (1998) "the decrease in reliability resulting from categorisation can result in high levels of measurement fuzziness and lead researchers to observe patterns that

do not exist or to overlook natural patterns that do exist" (p.103). Additionally, as categorically insecurely attached children form a small proportion of the general population, there is reduced statistical power to detect an effect. Therefore large sample sizes are needed to avoid inflation of type II errors (i.e. failure to find an effect which truly exists in the population). Accordingly, the type of assessment used, and associated sample size, may affect whether a relationship between attachment and emotion understanding is found. No studies in this review reported a-priori power calculations used to determine sample size. Thus, determining whether these studies are fully powered to detect effects is problematic. Indeed the sample sizes on the whole appear reasonably small, particularly as in many cases, the samples were split into securely attached and insecurely attached groups, and given that many papers used numerous correlational analyses within one study. Therefore we may posit that some of the results were due to Type I or Type II errors.

ii. Study design

All studies in this review focused on correlational rather than causational evidence. Although many studies are longitudinal, and thus provide more convincing evidence of a true link between attachment and emotion understanding, only intervention studies can provide such causational data. Research has demonstrated that it is possible to alter the relationship between attachment and later outcomes through factors such as sensitive parenting (Belsky & Fearon, 2002). These factors can be successfully targeted through interventions (Bakermans-Kranenburg, Van Ijzendoorn & Juffer, 2003). Thus, measurement of emotion understanding before and after an intervention aimed at increasing parental sensitivity (and therefore increasing security of attachment) would provide stronger evidence for a direct causal link.

Attempts were made to control for a range of variables, such as verbal IQ and maternal depression, both of which have been associated with emotion

understanding/Theory of Mind abilities (e.g. Milligan, Astington & Dack, 2007; Pons, Lawson, Harris & De Rosnay, 2003), however, the use of control variables was inconsistent. This is not necessarily due to the quality of the studies, but rather that the studies ultimately all had different aims. Some set out to investigate the relationship between attachment and emotion understanding as a primary aim, but for others this was secondary. Additionally, some studies used novel, or poorly validated measures of emotion understanding, and few used blinding procedures. These methodological inadequacies, and inconsistent approaches to measurement of attachment and emotion understanding, constrain the analysis of findings. The literature would thus benefit from larger, well-controlled studies.

Implications

The relationship between attachment and emotional Theory of Mind/emotion understanding is in support of the Attachment Status Model proposed by Harris (1999). Further evidence for this model emanates from the fact that the relationship between attachment and emotion understanding was seen to remain once children's verbal abilities were controlled for. However, in some cases, the relationship did not remain after controlling for children's verbal abilities. Moreover, the studies reviewed have shown that maternal mind-mindedness and maternal mental state language may mediate, or perhaps completely account for, the relationship between attachment and emotion understanding. This supports Harris' Psychological Discourse Model (Harris, 1999).

Harris (1999) posits that the models are not mutually exclusive, and accordingly attachment pattern and maternal discourse may both make independent contributions to the development of emotion understanding. Indeed, the results in this review suggest that a multi-factorial pathway to emotion understanding is likely, with attachment and language two of the important contributors.

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Part 2: Empirical Paper

Development of a novel EEG paradigm to investigate the neural correlates of children's emotion understanding

Abstract

Aims

This research aimed to develop a novel Electroencephalography (EEG)/Event Related Potentials (ERPs) paradigm to measure the neural correlates of children's emotion understanding. The research secondarily aimed to associate ERPs with attachment security and socio-emotional competence.

Methods

Thirty-three six-year-old children, who had had their attachment to their primary care-giver profiled at twelve months, completed the EEG paradigm. Mothers also completed questionnaire measures assessing the child's socio-emotional competence and executive function.

Results

A Late Positive Potential (LPP) was found to be associated with emotion understanding. The LPP effect was not correlated with attachment status or socio-emotional competence.

Conclusions

Emotion understanding appears to share similar neural correlates with cognitive Theory of Mind understanding in young children.

A recent review of emotional and social competence in children, undertaken by Denham (2007), stated:

"children from preschool to the early primary years, who understand emotions, are more pro-socially responsive to their peers, show more adaptive social behaviour and are rated as more socially competent by teachers and peers alike" (p.18).

Consistent with this, a number of studies have found good emotion understanding to be associated with many positive outcomes in children, including: good moral reasoning (Lane, Wellman, Olson, LaBounty & Kerr, 2010); positive perceptions of social experiences (Dunn, 1995); positive peer relationships (Caputi, Lecce, Pagnin & Banerjee, 2012) and better educational outcomes (Garner, 2010) in childhood; and skills in managing one's emotions, a sense of subjective well-being, and adaptive resilience in adolescence (Lau & Wu, 2012).

Conversely, deficits in emotion understanding have been linked to various markers of psychological distress, psychopathology (Southam-Gerow & Kendall, 2002), and poorer educational outcomes (Garner, 2010) in childhood. Impairments in emotion understanding abilities have also been demonstrated in a number of specific clinical populations, such as in children with Autism Spectrum Disorders (ASD; Golan, Baron-Cohen & Golan, 2008), Attention-Deficit Hyperactivity Disorder (ADHD; e.g. Da Fonseca, Seguier, Santos, Poinso & Deruelle, 2009), and maltreated children (Luke & Banerjee, 2012).

Broadly, emotion understanding is comprised of recognition of emotion expression, and knowledge about: the causes of emotions; cues for feelings; knowledge of multiple emotions; methods of intentionally using emotion expression to communicate with others; and methods of coping with emotions (Garner, 2010; Southam-Gerow & Kendall, 2002). A narrow definition of emotion understanding is the ability to make sense of another person's emotions based upon contextual

information (e.g. Weimer, Sallquist & Bolnick, 2012). Individual differences in emotion understanding have been observed in early childhood, remain significant in middle childhood, are relatively stable across time, and are seen across multiple facets of emotion understanding (see Pons & Harris, 2005, for a review).

Given the stability of these early individual differences, and the obvious importance of emotion understanding to children's well-being, it is crucial to determine the antecedents and developmental trajectory of these skills. However, Southam-Gerow and Kendall (2002) argued that ''although … emotion is considered a cornerstone of human experience, many current theoretical models … have not adequately considered the role of emotion in development and psychopathology'' (p. 189). In particular, there is currently a lack of research regarding the neural mechanisms associated with emotion understanding in children; a gap that this research aimed to address.

Neural activity associated with emotion understanding

A key neuroscientific methodology particularly suited to paediatric populations is the use of Electroencephalograms (EEG; e.g. de Haan & Thomas, 2002). EEG uses electrodes placed on the scalp to measure electrical activity in the brain. Sensory, cognitive or motor stimuli may be used to evoke changes in the EEG waveform, caused by groups of neurons in the same area responding simultaneously (Luck, 2005, p. 35).These changes are known as Event Related Potentials (ERPs). ERPs are 'time locked' to specific stimuli. Unlike fMRI, they directly measure neural activity and have 'exceptional temporal resolution' (Hajcak, MacNamara & Olvet, 2010). In addition, the participant sits in an open room with the experimenter and not inside a scanner, as in fMRI or MEG, and this methodology is thus generally more acceptable for participants, particularly children.

ERPs are usually named in accordance with the timing of the maximum amplitude, and whether they are positive or negative in valence. They are

categorised according to timing, morphology, scalp topography and response to experimental manipulation (Hajcak et al., 2010). A number of ERPs have been associated with emotion processing (see Eimer & Holmes, 2007; Hajcak et al., 2010; Ibanez et al., 2012; Olofsson, Nordin, Sequeira & Polich, 2008, for recent reviews).

There is a vast literature on ERPs associated with emotion recognition (e.g. Balconi & Pozzoli, 2007; Eimer & Holmes, 2007; Kestenbaum & Nelson, 1992; Lang, Nelson & Collins, 1990). Little research has been carried out to assess ERPs associated with understanding emotions in context (hereinafter referred to as 'emotion understanding'), however. The neuroscientific studies most closely related to emotion understanding in children are those investigating Theory of Mind (Premack & Woodruff, 1978; e.g. Bowman, Liu, Meltzoff & Wellman, 2012; Liu, Meltzoff & Wellman, 2009; Liu, Sabbagh, Gehring & Wellman, 2004, 2009; Meinhardt, Kuhn-Popp, Sommer & Sodian, 2012; Meinhardt, Sodian, Thoermer, Dohnel & Sommer, 2011; Sabbagh, Bowman, Evraire & Ito, 2009; Sabbagh & Taylor, 2000). Theory of Mind (ToM) comprises the ability to predict another person's *cognitions* based on the viewer's knowledge of the situation or context. Similarly, emotion understanding is the ability to predict another person's *emotions* based on the viewer's knowledge of the situation or context. ERP studies have reliably associated cognitive ToM with the presence of a late, anterior slow wave (see Meinhardt et al., 2011 for a review).

Consistent with this, Liu, Sabbagh and colleagues (2009) found that during a false-belief task, adults, and children capable of understanding Theory of Mind, demonstrated the presence of Late Positive Slow waves (LPP) 775 ms - 850 ms post stimulus, occurring at left-frontal electrodes. In their study, children were shown film clips of false-belief eliciting stimuli. A cartoon figure was shown to place two animals in two different boxes; the character then stands in front of the boxes, and the animals are seen to move to different boxes, out of sight of the cartoon

figure. The participants are then asked a 'reality question' – 'where is this animal really?' and a ToM (belief) question 'where does the person think this animal is?'. The participants either answered the questions verbally or by pointing. The researchers found an LPP associated with belief reasoning, in adults, and children capable of understanding ToM (the children who 'passed' at least 75% of trials). This effect was not seen in children who did not understand ToM (i.e. who passed fewer than 25% of trials), suggesting that the LPP may be a neural correlate of ToM processing. Similar effects of LPP have also been demonstrated in passive viewing ToM tasks (Geangu, Gibson, Kaduk & Reid, 2013), which do not require a response. Earlier positivity across temporo-parietal areas (around 300 ms after stimulus onset; the 'P3') has also been associated with belief-reasoning (e.g. Bowman et al., 2012; Liu, Meltzoff et al., 2009; Meinhardt et al., 2011; Sabbagh & Taylor, 2000).

Additionally, there may be developmental effects on the localisation (Meinhardt et al., 2011), and timing (Liu, Sabbagh et al., 2009), of the neural response associated with ToM functioning; Liu, Sabbagh and colleagues (2009) found that the LPP effect was later and more diffuse in children, compared to adults. Meinhardt and colleagues (2011) demonstrated a more posteriorly localised Late Positive Complex (LPC) and Late Anterior Slow Wave (LSW; the 'P3' ERP) in children, compared to adults. They used a standard ToM task of unexpected transfer. In this, a character is seen to leave an object in one location. The first character then leaves the room, and a second character moves the object to a new location. The participant is asked where the first character would search for the object. Stimuli varied in two ways; belief and expectation. True belief conditions occurred when the first character *believes* the object to be in the place that it *really* is. Conversely, false-belief conditions occurred when the character believes the object to be in a different place to where it really is. Expected conditions occurred when the character then searched for the object in the place we assume they believe it to be, and unexpected conditions occurred when the character searched in

a location incongruent with their presumed belief. False-belief conditions were associated with a significantly greater LPC and LSW than true-belief conditions. Additionally, unexpected outcomes were associated with a greater LPC over midline electrodes than expected outcomes, although there was no reliable effect of expectancy on the LSW.

Brain regions implicated in ToM include the posterior Superior Temporal Sulcus (pSTS), Temporo-Parietal Junction (TPJ), temporal poles and the medial Pre-Frontal Cortex (mPFC; Frith & Frith, 2006). These areas of activation complement ERP findings of LPP (associated with electrodes over prefrontal areas), and P3 (associated with temporo-parietal electrodes). This seems to hold true for paediatric populations (e.g. Bowman et al., 2012), although there is mounting evidence for a decrease in mPFC activation during ToM tasks in adolescents compared to adults (Blakemore, 2008). Differences in neural activity (EEG alpha waves) in the dorsal medial Pre-Frontal Cortex (dmPFC) and right TPJ (rTPJ) have been positively correlated with 4-year-old children's performance on a Theory of Mind task, even when controlling for Executive Function abilities (Sabbagh et al., 2009).

Similar regions have been implicated in emotion understanding/affective ToM tasks (e.g. Burnett, Bird, Moll, Frith & Blakemore, 2009). However, cognitive and affective ToM may recruit slightly different neural populations; Sebastian and colleagues (2012) found increased mPFC activation in an emotion ToM task (inferring how a character would react to their companion's affective state, based on an understanding of their emotions), compared to a cognitive ToM task (inferring how a character would react based on an understanding of their companion's intentions or beliefs), in adolescents and adults. In light of the commonalities between the two abilities, and the possibly overlapping brain systems (Sebastian et al., 2012), EEG studies of ToM provide the best framework for thinking about the brain processes that might be engaged in emotion understanding in children.

To our knowledge, there has been no research investigating the neural correlates of *emotional*, rather than cognitive ToM understanding in children. Therefore, in this study, we aimed to develop and pilot a paradigm to investigate emotion understanding in 6-year-old children (the beginning of 'middle childhood'). This age-group was chosen because middle childhood is a key time for social-emotional development, as children enter a more social world at school and are less reliant on their parents (Colle & Del Giudice, 2011). Thus, emotion understanding at this age is thus crucial for forming peer relationships. Additionally, this is the age at which children can reliably understand and pass ToM tasks (Wellman & Liu, 2004).

The paradigm combines knowledge of Theory of Mind related ERPs and Violation of Expectation negativity potentials in EEG with methodology used in a previous study of emotion understanding in young children (Steele, Steele & Croft, 2008; Steele, Steele, Croft & Fonagy, 1999).

Violation of expectation

A number of studies have consistently shown a negative potential 400 ms post-stimulus in response to a violation of expectations (Kutas & Federmeier, 2011). Typically, this has been found following the presentation of semantically unrelated information, such as between two words or between a word and a context (Ibanez et al., 2012). However, the N400 has been seen across modalities, and recently has been demonstrated in studies of emotion processing. Leuthold, Filik, Murphy and Mackenzie (2012) presented adults with sentences describing the context of a scenario and the emotional response of a character involved in the scenario. They demonstrated an N400 (localised to the anterior temporal lobe), followed by a larger frontal positivity (LPP), when the emotional response was incongruent with the context. These effects were not seen when the context and emotion matched. The authors propose that the LPP 'reflects high-level mindreading functions', which would be consistent with LPP findings in ToM studies. This again suggests a

relationship between neural responses to emotion understanding and cognitive ToM tasks.

Similarly, Goto, Yee, Lowenberg and Lewis (2013) used a visual equivalent, whereby adult participants were presented with a visual scene. A large face was then superimposed on the scene. The emotional expression displayed by the face was either congruent or incongruent with the scenario. Again, a greater N400 was seen for the incongruent scenes in Asian-American participants. The N400 was symmetrical across hemispheres and was greatest at midline centro-posterior electrodes. Interestingly, the effect was not seen in European-American participants, which the authors attribute to reduced attention to social context in this population. To our knowledge, there have not been similar studies investigating emotion understanding in children, although analogous paradigms have been used to investigate cognitive Theory of Mind (e.g. Meinhardt et al., 2011).

Development of the paradigm

In order to develop a rigorous paradigm that could be used to elicit ERPs in children, we modified an existing task used by Steele and colleagues (1999, 2008), which investigated emotion understanding in 6-year-olds. In this earlier study, 63 children were shown line drawings depicting the 6 basic emotions described by Ekman (1971); happy, sad, angry, surprised, disgust and fear; two mixed emotions – mischief (happy/angry) and disappointed (sad/surprised); and a neutral face. Participants were asked firstly to label the faces (an emotion recognition task). Secondly, researchers told the participants which emotion the faces were intended to depict. In the next part of the task, the children were shown cartoon-sequences, in which a cartoon character was firstly shown in a scene and with a corresponding emotion displayed on their face (e.g. a child with a smiling face holding an ice-cream). In the next image, the scene changes (e.g. the child has dropped the ice-cream) and the child's face is blank, with no facial expression. The cartoon

sequences were shown one at a time and the experimenter read an accompanying narrative. Finally, the child was asked to choose an emotional face which fitted the final scene (i.e. to fill in the blank face) and explain to the experimenter why this face was chosen. The experimenter then asked if any other faces would 'fit', in order to assess the child's understanding of mixed or ambivalent emotions.

In the present study, a similar task was used, but the final emotional face for each cartoon was provided for the participants, rather than leaving a blank face. Similarly to the design employed by Goto and colleagues (2013) for emotion understanding in adults, and Meinhardt and colleagues (2011) for belief understanding, the emotional expressions were either congruent (e.g. sad that they have dropped their ice-cream) or incongruent (e.g. happy that they have dropped their ice-cream) with the scene. We anticipated that incongruent emotions would elicit a negativity related to violation of expectations (an N400). Furthermore, incongruent scenes were expected to evoke a larger Late Positive Potential (LPP), and P3, as the child tries to understand the protagonist's unanticipated emotional response.

Association with attachment

The attachment relationship to the primary caregiver has been posited as one of the mechanisms through which emotion understanding is developed. The concept of attachment was first described by Bowlby (1969) as the "lasting psychological connectedness between human beings" (p.194). He proposed attachment theory "as a way of conceptualizing the propensity of human beings to make strong affectional bonds to particular others" (Bowlby, 1977, p. 201). His theories particularly describe the physical and emotional bond between an infant and its primary caregiver, usually its mother. Four main attachment patterns have been proposed, which describe how an infant relates to its primary care giver: secure, avoidant-insecure,

ambivalent insecure (Ainsworth, 1978) and disorganised insecure (Main and Solomon, 1990).

Fonagy and Target (2002) hypothesise that the attachment relationship acts as the mechanism through which mental events are appraised and reorganised. They hypothesise that secure attachment allows for the development of a capacity to 'mentalise'; i.e to have a mental representation of others' minds. They further posit that "internal states must have meaning so that they may be communicated to others and interpreted in others to guide collaboration in love, work and play" (Fonagy & Target, 2002, p. 321). Consistent with this, child-mother attachment has been shown to be related to peer relationships in middle-childhood (Schneider, Atkinson, & Tardif, 2001). Part one of this thesis reviewed a number of studies investigating the relationship between security of attachment and emotion understanding. Most found that a more secure attachment was linked to improved emotion understanding. In light of these findings, we correlated the results of the emotion understanding EEG task with the participant's attachment pattern to their primary care giver.

In summary, this research therefore aimed to:

1) Develop a task, suitable for 6-year-old children, in which the neural activity associated with their ability to predict other people's emotions (i.e. emotion understanding) could be investigated.

We hypothesised that emotion prediction would result in a negativity (N400) in incongruent trials relative to congruent trials. We also predicted the presence of a larger Late Positive Potential (LPP), and P3, in incongruent trials relative to congruent trials.

2) Investigate whether the neural activity associated with emotion understanding correlates with children's social competence at 6 years old.

As previous research has identified a positive correlation between children's emotion understanding and social competence, we anticipated a positive correlation between neural activity associated with emotion understanding (LPP, N400 and P3), and social competence.

3) Investigate whether the neural activity associated with emotion understanding at 6 years old correlates with attachment security to the primary care giver at 12 months old.

We predicted that children who were securely attached to their primary care giver aged 12 months would show greater N400 and LPP amplitudes in response to the incongruent emotion trials relative to the congruent trials.

Methods

Setting

The study took place at a North London Child and Adolescent Mental Health Clinical and Research Centre.

Participants

The sample comprised 47 children (25 males), and their mothers (see Figure 1 for flow-diagram of participation). Ages ranged from 69 to 81 months (M = 73.13, SD = 2.63 months). All child-mother dyads were from a cohort of children who had their attachment pattern assessed at 12 months old, using the Strange Situation (Ainsworth et al., 1978). We approached all 96 parents of children from this original cohort who had given permission for us to do so (a 47% follow-up rate). Initial contact was by letter (which included a participant information leaflet; see Appendices B, C, and D for study documentation), followed by a telephone call. Children with a diagnosed Developmental Disability, including Autism Spectrum Disorder (ASD), were excluded from the study. All participants were offered a £5 book voucher as compensation for their time.

Questionnaire data was completed for all 47 participants; however 1 participant was later excluded due to a diagnosis of ASD (not disclosed until participation). Three participants did not complete the EEG task, due to skin allergies and/or anxiety about the procedure. Data from an additional 10 children were excluded due to excessive movement artefacts or technical errors during EEG recordings. This attrition rate is in line with other ERP studies using younger children (e.g. Meinhardt et al., 2011). Therefore, the final EEG sample consisted of 33 children (14 males; mean age = 72.88 months, SD = 2.37 months; range = 69-78 months; 26 securely attached, 7 insecurely attached). Participants primarily came from white, middle-class families. Full demographic information is detailed in Appendix E.

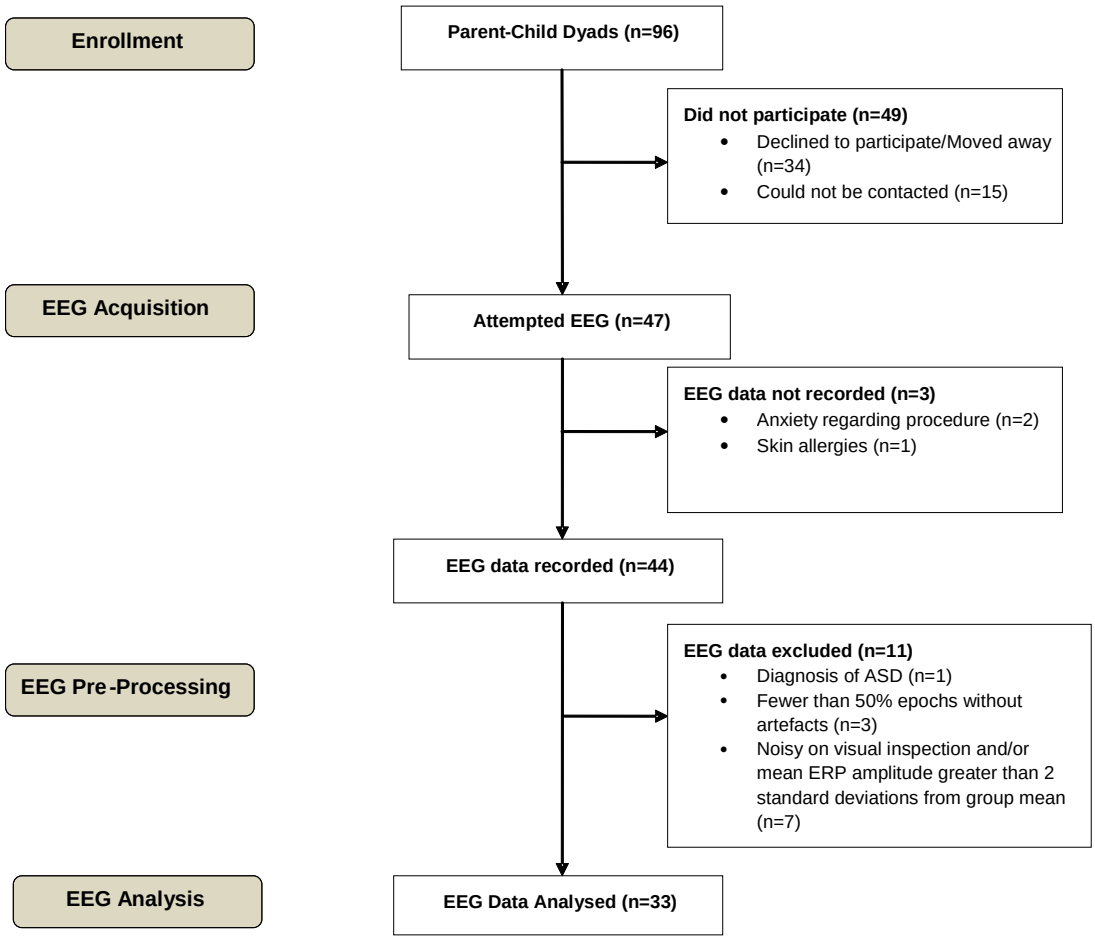


Figure 1. Flow diagram of participant recruitment and attrition.

Power calculations

Power calculations were performed to aid with decisions regarding sample size. Meinhardt and colleagues (2011) found a significant difference in LPP amplitude over midline sites between false-belief and true-belief trials in their study assessing the neural correlates of Theory of Mind processing, $F(1,41) = 20.01$, $p < .001$. To detect an effect of this size between ERP amplitude in congruent and incongruent trials, at 80% power and 5% significance, 11 participants were required.

Steele and colleagues (2008) found that the correlation between 6-year-olds' ability to identify emotions with infant-mother attachment was .41. To detect a correlation of this size between emotion understanding and infant-mother attachment, at 80% power and 5% significance, 44 participants were required.

Therefore, due to high attrition rates within this population (Meinhardt et al., 2011 reported a 35% attrition rate in their child participants), we aimed to recruit 70 participants.

Design

The study was a longitudinal cohort study involving EEG, behavioural tasks and questionnaire measures. It forms part of a joint-submission, with two studies undertaken with the same participant group. The present study investigated the socio-emotional development of children, and the second study (Carman, 2013) investigated the development of control of actions. Please see Appendix A for further information regarding the contribution of each trainee to the project. Thus, children completed two tasks, with task order counterbalanced over all testing sessions. One task, investigating response inhibition, is not reported here. In total, each task took approximately 20 minutes and participants were offered a break in between tasks.

Following completion of the two EEG tasks, participants were given a 10-minute refreshment break. The Story Stems Assessment Profile (Hodges, Steele,

Hillman, Henderson & Kaniuk, 2003) was then administered, to provide a concurrent measure of attachment pattern. These data were collected as part of a separate study, and are not reported presently. Mothers completed questionnaire measures whilst their child was completing the EEG tasks. In total, participation took approximately 2 hours, including time for informed consent and thorough explanation of the study. Researchers were blind to the attachment pattern results of the Strange Situation (Ainsworth et al., 1978) until analysis was undertaken.

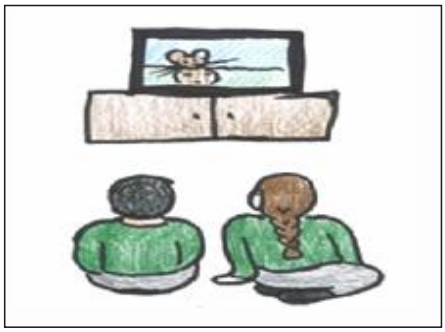
Procedures

EEG task

EEG methodology was used to investigate neural responses to a socio-emotional task. The task was based on a task previously used by Steele and colleagues (1999, 2008). The task comprised static cartoon scenes, involving a child character, in which a two - or three - scene story would unfold. Audio description of the scene accompanied each picture. The final scene involved a child with a 'blank' face. The Audio recording asks the participant how they think that child would be feeling. The child's facial expression would then be 'revealed' (Figure 2). Participants were instructed to stay as still as possible whilst watching the scenes and to think about how the cartoon child would be feeling in their heads.

40 cartoon scenarios were shown; 20 where the target child would be expected to experience a positive emotion, and 20 where they should experience a positive emotion (Appendix F). Scenes ended with a facial expression that was either congruent or incongruent with the scene. There were 10 incongruent negative scenes (i.e. scenes that unexpectedly ended with a negative emotion), 10 congruent negative scenes (i.e. ended with a negative emotion as expected), 10 incongruent positive scenes (i.e. unexpectedly ended with a positive emotion) and 10 congruent positive scenes (i.e. ended with a positive emotion as expected). Scenarios were presented in a random order, and each scene was used only once for each

participant. Congruent and incongruent versions were created for each of the 40 scenes. Thus, two versions of the task were created, and counterbalanced so that half of the participants viewed the congruent version of a certain scene and half viewed the incongruent version of it. This controlled for potential confounding factors, such as differences in the basic visual properties of positive and negative scenes.



1. 'Jack and Emily are watching cartoons after school'.

2. 'Mum comes in and tells Emily that she has to do her homework before she can watch TV'.

3. 'So Emily does her homework in the kitchen whilst her brother watches TV in the living room. I wonder how she's feeling?'.

4. (Face revealed – ERP eliciting stimulus).

Figure 2. Example of EEG stimuli.

Participants sat in a dark, sound attenuated room whilst the tasks were presented on a computer monitor, situated approximately 41 cm away from the participant. The images were approximately 18 cm square, with subtended visual angles of 253.74º horizontally and vertically. Each ERP eliciting image (the image in which the facial emotion was shown), was presented for 2000 ms, following the

presentation of the same image without a facial expression. The Inter-Stimulus Interval (ISI) between scenes within a scenario was 0 ms, and the ISI between scenarios was 500 ms (Figure 3). The ERP data were time-locked to the presentation of the image in which the facial emotion was shown. Stimuli presentation was controlled using the E-Prime 2.0 Software (Psychology Software Tools, Pittsburgh, PA).

Attachment pattern at 12 months

Attachment pattern at 12 months was assessed using the Strange Situation (Ainsworth, 1970). In this, a child is placed in various scenarios with a combination of their mother and/or a stranger, as follows: 1. Parent and infant alone. 2. Stranger joins parent and infant. 3. Parent leaves infant and stranger alone. 4. Parent returns and stranger leaves. 5. Parent leaves so infant is alone. 6. Stranger returns. 7. Parent returns and stranger leaves. Attachment classifications derived from this procedure have been shown to be reliably stable across time (Main, Kaplan & Cassidy, 1985), and inter-rater reliability is high; Ainsworth and Bell (1970) found a 94% agreement between raters.

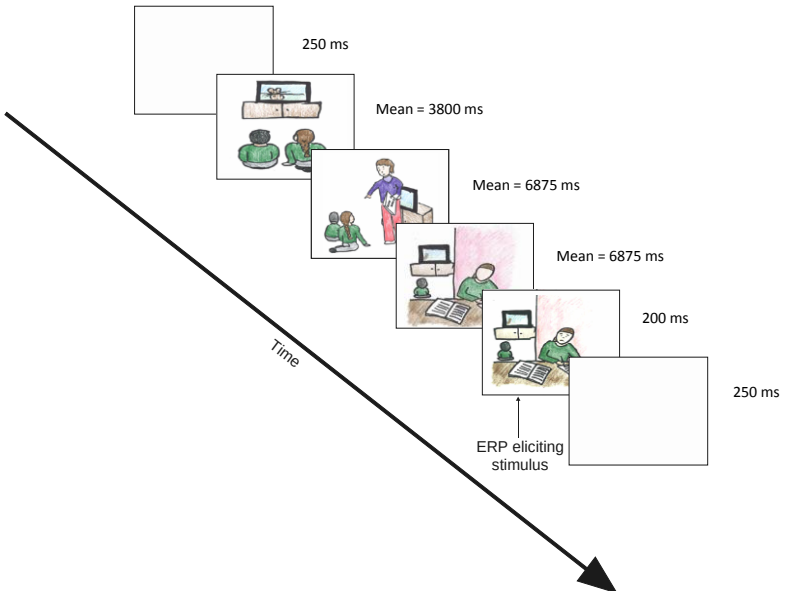


Figure 3. EEG experiment design.

Electroencephalography (EEG) acquisition and preprocessing

EEG data were collected and recorded online using Electrical Geodesics, Inc. 129-channel sensor nets (Tucker, 1993), NetAmps Series 300 amplifier (Electrical Geodesics, Inc.) and NetStation software. The data were amplified and sampled at a frequency of 250 Hz. An anti-aliasing low-pass filter of 70 Hz was applied during data acquisition.

Measures

Social competence

Parent-report data regarding children's social competence was collected using the Social Competence Scale – Parent Version (Conduct Problems Prevention Group, 1995; Appendix G). This is a 12-item scale which comprises 2 subscales: a prosocial and communication subscale and an emotional regulation skills subscale. Some items from this questionnaire were adapted from the Kendall and Wilcox (1979) and Gesten (1976) assessments of social competence. Parents are given 12 statements, 6 from each subscale, describing behaviours that their child may display in a social setting, for example 'your child can give suggestions and opinions without being bossy' and 'your child listens to others' points of view'. These statements are rated on a five point Likert scale, according to how well the statement fits the child, from 0 (not at all), to 4 (very well). The total scores are summed and averaged across the number of responses to give an overall score, and scores for each of the subscales. This measure has good internal consistency (Cronbach's α for normative sample = .89), and significant differences on total and subscale scores have been demonstrated between normative and at-risk groups (Corrigan, 2003).

Additionally, parents completed the full Informant-rated Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). This comprises 25 questions, with 5 scales, each of 5 items. For each item, parents are given a statement describing their child, and asked to score them on scale of 0 (not true), 1 (somewhat

true), or 2 (certainly true). For this study, only the 'prosocial' and 'peer' subscales were used, which include items such as 'my child is considerate of other people's feelings' and 'my child has at least one good friend'. This measure is used widely in the United Kingdom, and studies have demonstrated good reliability (mean Cronbach's α = .73; Goodman, 1997), and validity (e.g. Goodman, 2001).

Executive Function

As Executive Function (EF) has reliably been associated with ToM abilities (e.g. Aboulafia-Brakha, Christe, Martory, & Annoni, 2011), parents completed the Behaviour Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy & Kenworthy, 2000), to allow EF to be added into analyses as a covariate. The scale comprises 86 items, covering 2 indices (metacognition and behavioural regulation). The metacognition index is further subdivided into five subdomains (monitor, organisation of materials, plan/organise, working memory, initiate), and the behavioural regulation index can be further divided into emotional control, shift, and inhibit subdomains. Each item involves a statement regarding the behaviours of the child, which the parents rate according to the frequency of the behaviour (never, sometimes, or often). Satisfactory reliability and validity have been demonstrated; Cronbach's α ranges from .80 to .98 (Gioia et al., 2000).

Analysis

Offline, the EEG data were band-pass filtered between 0.1 and 30 Hz and converted to an average reference, using EEGLAB software (Delorme & Makeig, 2004). The continuous EEG was segmented into epochs between -200 ms and 1500 ms relative to stimulus onset. Spline interpolation was carried out on individual channels if required. Epochs were excluded from analysis if they met any of the following artefact rejection criteria: voltage deviations exceeded ±175 μV relative to baseline, the maximum gradient exceeded 150 μV, or activity was lower than 1 μV.

Participants were excluded if over 20 epochs (50%) were rejected; 2 participants were excluded due to this criteria. See Table 1 for details of electrodes used for each ERP component, and Appendix H for map of electrodes.

ERPs were constructed by separately averaging responses for positive congruent, positive incongruent, negative congruent and negative incongruent trials. For each ERP average, the average activity in the 500 ms window prior to the picture onset served as the baseline. At this stage, participants were excluded from analyses if the mean LPP ERP was greater than two standard deviations from the mean, or if visual inspection of the data revealed a significant amount of noise due to movement or technical error. Data from a further 7 participants were excluded due to this criteria, giving a final EEG sample of 33 participants.

For the final sample, the mean number of interpolated channels was 8.62 (SD = 4.33; range = 0-13 channels). Across participants, a mean of 86% of trials (SD = 12%; range = 61-100%) were retained after filtering and artefact rejections. The total number of epochs analysed per condition were: 270 (negative congruent), 281 (negative incongruent), 241 (positive congruent) and 282 (positive incongruent). ERPs were statistically analysed using SPSS General Linear Model software (IBM Corp., 2012). ERP data were then correlated with the scores from the Social Competence Scale. A repeated measures ANOVA was used to analyse the effect of attachment pattern on mean ERP amplitude within each time window.

Ethics

Full ethical approval was gained from the UCL Research Ethics Committee (ID: 3594/001; Appendices Ia & Ib).

Results

Results are presented in three parts. First, data regarding ERPs related to emotion understanding are presented. Secondly, in order to control for differences in the

basic visual properties of the stimuli, ERPs related to early visual processing are reviewed. Finally, the paper presents results regarding the association between ERPs and measures of social competence, and ERPs and attachment security.

ERP data

As described previously, ERPs were analysed by creating grand average wave-forms for selected electrodes and time periods, for all four stimulus conditions (negative congruent, negative incongruent, positive congruent and positive incongruent). Effects of congruency (congruent versus incongruent scenes) and emotional valence (scenes expected to end with a positive emotion versus those expected to end with a negative emotion) were examined with 2 x 2 (congruence x valency) fully within-subject Analysis of Variances (ANOVAs). Mean amplitudes for selected time periods were used in all cases. The Greenhouse-Geisser correction for non-sphericity was applied to *p*-values associated with more than one degree of freedom. Descriptive statistics, along with the selected electrodes for each ERP, are outlined in Table 1. Significance is considered at the .05 level.

ERPs associated with emotional/ cognitive ToM processing: P3, LPP & N400

LPP, N400 and P3 components were firstly investigated, as these have been previously associated with emotion understanding and/or ToM (Figure 4). The LPP demonstrated significant effects of congruency, $F(1, 32) = 27.818$, $p = <.001$, $\eta\rho^2 = .465$, but not of valence, $F(1, 32) = .336$, $p = .566$, $\eta\rho^2 = .01$, nor any interaction between valence and congruence, $F(1, 32) = .316$, $p = .578$, $\eta\rho^2 = .01$. Analysis of the P3 demonstrated no significant effects of valence, $F(1, 32) = .318$, $p = .577$, $\eta\rho^2 = .01$, congruency, $F(1, 32) = .488$, $p = .490$, $\eta\rho^2 = .015$, nor interaction effects, $F(1,32) = 3.010$, $p = .092$, $\eta\rho^2 = .086$.

The N400 demonstrated no significant main effects of valence, $F(1, 32) = 3.200$, $p = .083$, $\eta\rho^2 = .091$; nor congruency, $F(1, 32) = .289$, $p = .594$, $\eta\rho^2 = .009$, nor interaction effect, $F(1, 32) = 3.790$, $p = .060$, $\eta\rho^2 = .106$.

Topographic maps of the congruence effect (congruent vs. incongruent stimuli) are shown in Figure 5, demonstrating significant effects of congruency over frontal electrode sites for later epochs (the LPP).

Table 1

Mean Amplitudes for Selected ERPs

ERP	**Electrodes**	**Time period (ms)**	**Mean negative congruent μv (SD)**	**Mean negative incongruent μv (SD)**	**Mean positive congruent μv (SD)**	**Mean positive incongruent μv (SD)**
P1	Right & Left Occipital: 65, 69, 70, 83, 89, 90	100-200	3.325 (4.562)	2.984 (4.500)	3.732 (5.573)	1.674 (3.433)
N1	Right& Left Occipital: 65, 69, 70, 83, 89, 90	200-300	1.204 (5.227)	0.637 (5.799)	2.312 (6.407)	-.294 (4.373)
P3	Midline Parietal: Pz (62)	300-600	4.628 (6.612)	5.361 (6.269)	5.310 (6.015)	3.390 (7.123)
LPP	Midline Frontal: Fz (11)	700-1495	1.618 (6.432)	5.212 (5.173)	.649 (4.77)	5.203 (5.050)
N400	Midline Central: Cz (129)	300-500	-.971 (4.480)	.273 (3.830)	-.800 (6.224)	-2.733 (5.192)

ERPs associated with visual and face processing: N1, P1

To ensure that the LPP congruency effect was not due to differences in the basic visual properties of the stimuli (e.g. contrast), P1 and N1, which are correlates of early visual processing, were analysed (Figure 6). The P1 and N1 mean amplitudes

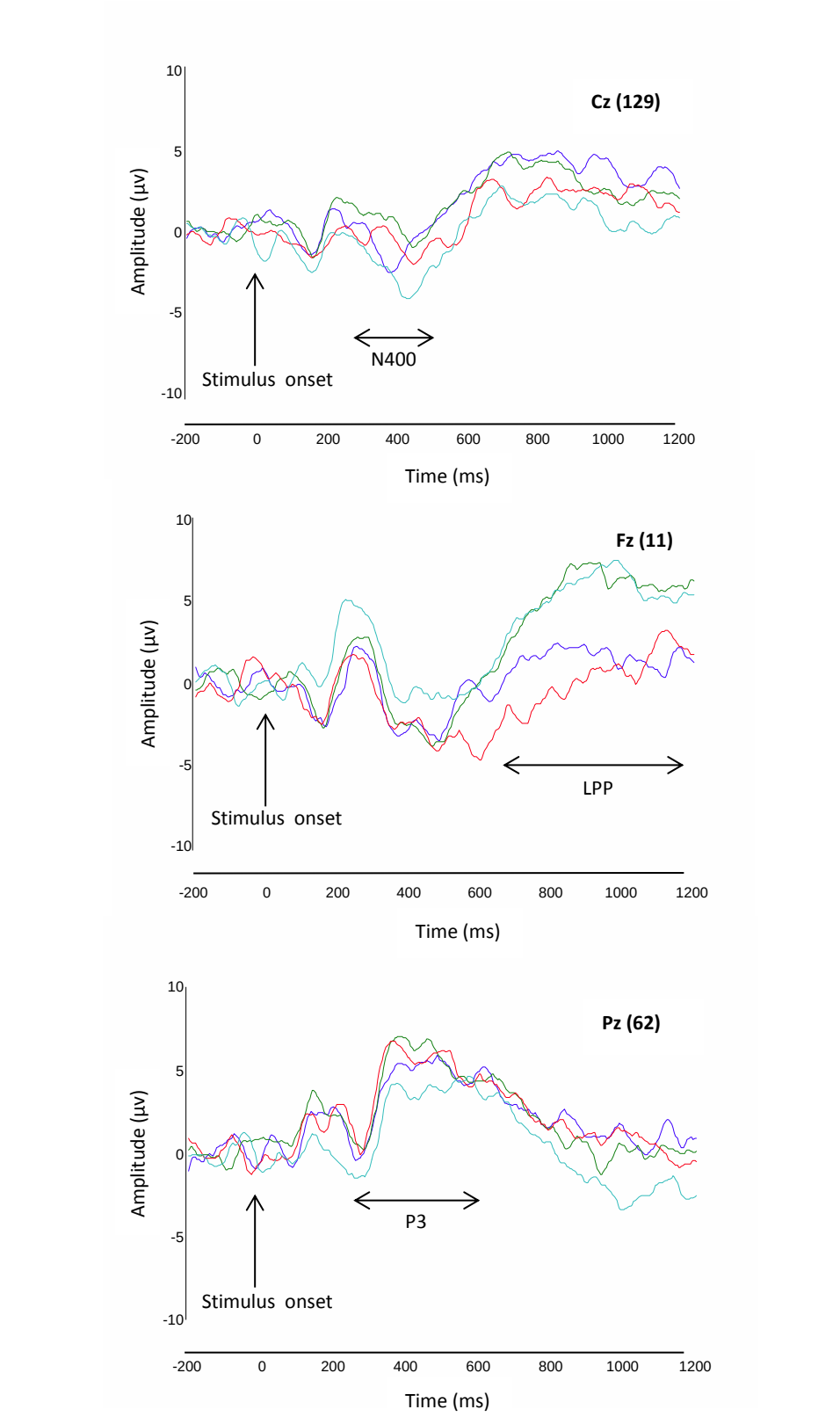


Figure 4. Grand average wave-forms elicited for negative congruent, negative incongruent, positive congruent and positive incongruent conditions, for ERPs previously associated with emotion understanding/ToM.

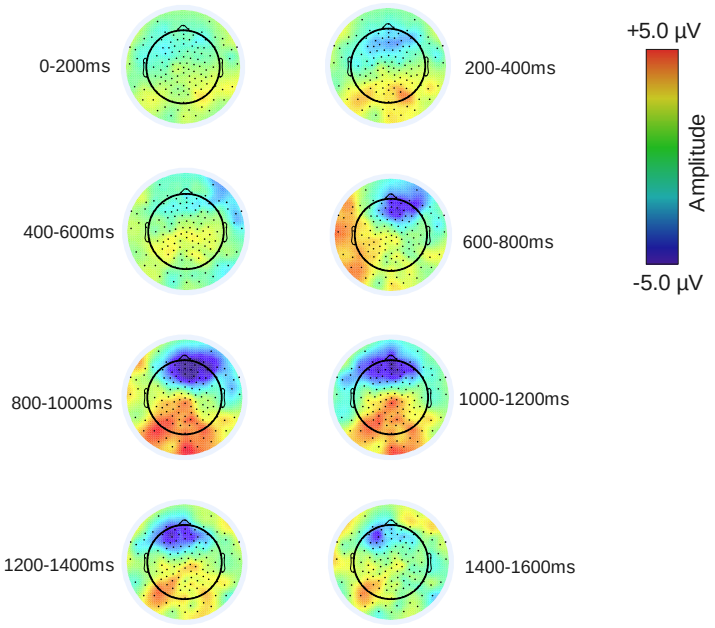


Figure 5. Topographic maps of the congruence effect, showing mean amplitude differences for congruent and incongruent conditions (congruent mean amplitude – incongruent mean amplitude) across 200 ms time periods.

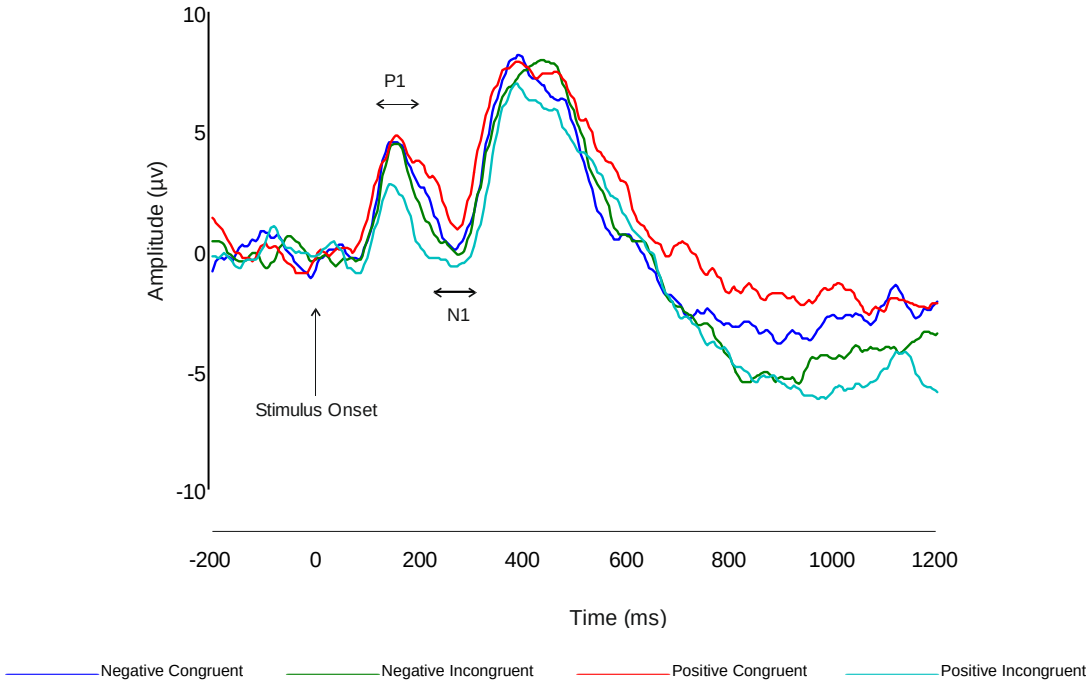


Figure 6. Grand average wave-forms elicited for negative congruent, negative incongruent, positive congruent and positive incongruent conditions, for ERPs previously associated with early visual processing.

showed no significant effects of congruency, $F(1, 32) = 3.284$, $p = .079$ (P1), $\eta\rho^2 = .093$; $F(1, 32) = 3.455$, $p = .072$ (N1), $\eta\rho^2 = .097$, or valence, $F(1, 32) = .282$, $p = .599$, $\eta\rho^2 = .009$ (P1); $F(1, 32)=.008$, $p = .928$, $\eta\rho^2 < .001$ (N1), nor a significant interaction between valence and congruency, $F(1, 32) = .1.702$, $p = .201$, $\eta\rho^2 = .05$ (P1); $F(1, 32) = 1.557$, $p = .221$ (N1), $\eta\rho^2= .046$.

Socio-emotional competence & attachment classification: relation to LPP

The only component related to emotional or cognitive ToM processing demonstrating a significant main effect of congruence was the LPP. Therefore, only this ERP was investigated further in terms of its relation to socio-emotional abilities and attachment classification. Table 2 provides descriptive statistics of the questionnaire measures used to assess socio-emotional competence.

A 2-way ANOVA was performed to examine the effect of attachment classification on the LPP congruency effect (congruency x attachment). Although a significant effect of congruency was again demonstrated $F(1, 31) = 14.367$, $p = .001$, $\eta\rho^2 = .317$, no significant effect of attachment was seen, $F(1, 31) = .233$, $p = .633$, $\eta\rho^2 = .007$, and there were no interaction effects, $F(1, 31) = .172$, $p = .681$, $\eta\rho^2 = .006$.

To examine the relationship between the LPP congruency effect and soci-emotional competence, questionnaire scores from the Social Competence Scale and SDQ subscales were correlated with the mean difference in amplitude between congruent and incongruent scenes. Again, there was no association between any of the questionnaire measures and the LPP congruence effect.

Additional analyses

Previous research has demonstrated age, gender and Executive Function abilities to be associated with ToM abilities. These factors were therefore investigated to determine the extent to which they were associated with the LPP congruence effect.

A 2 x 2 (gender x congruency) ANOVA demonstrated an overall effect of congruence, $F(1, 31) = 26.006$, $p < .001$, $\eta\rho^2 = .456$, but not of gender, $F(31,1) = .006$, $p = .939$, $\eta\rho^2 = .051$, and there was not significant interaction between the two, $F(31, 1) = 1.083$, $p = .306$, $\eta\rho^2 = .034$. Age and executive function (as assessed by the BRIEF total score), were not correlated with the congruence effect (Table 2).

Table 2

Descriptive Statistics of the Questionnaire Measures used to assess Socio-emotional Competence and Executive Function and Results of Correlations between Measures and LPP Congruency Effect.

Outcome measure	**Mean score/value**	**Standard deviation**	**Correlation with LPP congruency effect (incongruent – congruent) (r)**	**Probability of effect**
BRIEF General Executive Composite*	51.212	8.433	-.023	.897
Social Competence Scale (SCS) Mean Total	2.573	0.502	.018	.920
SCS Total	30.878	6.030	.028	.920
SCS Pro-social Subscale	2.900	0.564	.045	.804
SCS Emotion Regulation Subscale	2.240	0.568	-.012	.945
SDQ peer subscale	0.880	1.193	.103	.568
SDQ pro-social subscale	8.480	1.544	-.134	.457
SDQ total	6.940	4.069	-.224	.210
Age	72.880	2.369	-.174	.334

* These are T scores

Discussion

As with numerous studies investigating the neural processing of cognitive Theory of Mind (Meinhardt et al., 2011), this study demonstrated a Late Positive Potential

(LPP), over frontal electrodes, associated with emotion understanding. As far as we are aware, this is the first study to demonstrate such an effect for emotional, as opposed to cognitive, Theory of Mind in children. As hypothesised, the effect was greater for incongruent as opposed to congruent scenarios, presumably reflecting the increased cognitive capacity required to 'make sense' of an emotion that does not fit with the context. There was no effect of emotional valence; negative and positive scenes were seemingly equally difficult to process. The lack of congruence effects in ERPs related to early visual processing suggests that the LPP amplitude differences were a genuine effect of congruency, as opposed to differences in the visual properties of the congruent and incongruent stimuli. No significant main effects of congruency were seen for the P3, nor N400, components.

LPP

We hypothesise that the frontal scalp distribution of the LPP is related to activity within the prefrontal cortex. Although EEG does not have sufficient spatial resolution to confirm whether this is the case, previous imaging and ERP source analysis research has demonstrated prefrontal activity associated with cognitive ToM reasoning (e.g. Liu et al., 2004; Sabbagh et al., 2009). Liu, Sabbagh and colleagues (2009) suggested that, in accordance with other research, the LPP elicited from their cognitive ToM task was in part related to ''conceptual operations in verbal working memory" (p. 324). They also consider that it reflected 'domain-specific' ToM-associated activation, as previous research with tasks with similar working memory requirements still found an LPP associated with belief-reasoning, but not with control conditions. Similarly, we can assume that congruent and incongruent scenes within the present paradigm required similar levels of domain-general processing (such as language abilities, and working memory), and thus posit that the LPP effect is related specifically to emotion understanding (i.e. understanding the mismatch between expected and observed emotions in incongruent scenes).

The LPP effect was seen reasonably late within the epoch (from around 750 ms up to 1200 ms), perhaps reflecting the age of the children we tested. Other studies investigating ToM in children have suggested that these effects are later in the paediatric population (e.g. Liu, Sabbagh et al., 2009; Meinhardt et al., 2011); for example, Meinhardt and colleagues (2011) found the LPP at 600-900 ms for adults but between 750-1450 ms for children. This is consistent with other ERP research finding longer latencies in children compared to adults (Taylor & Baldeweg, 2002). Future research, testing children and adults of a range of ages with the present task (as in Meindhardt et al., 2011), would confirm whether this is indeed true for emotion understanding. Researchers have suggested that the late and long latency of the LPP provides evidence that, contrary to early proposals (e.g. Leslie, 1994), ToM understanding is *not* an 'automatic' process, akin to sensory or perceptual processing. Instead, it requires more controlled thought processes (Meinhardt et al., 2011). This study may suggest that emotion understanding, equally, requires more controlled processing. However, the LPP within this task is related to understanding the *mismatch* between the expected and observed emotion, and not necessarily the initial emotion understanding. Thus, it may be that the understanding of the mismatch is not automatic, but the initial emotion understanding is.

P3

Our research demonstrated a P3, which is also in line with previous studies of cognitive ToM (e.g. Meinhardt et al., 2011; Sabbagh & Taylor, 2000). However, previous studies have demonstrated that this is greater in trials of false-belief compared to true-belief conditions. Contrary to this, we found no significant difference in mean amplitude for congruent and incongruent scenes. Thus, we cannot conclude that the P3 relates to emotion understanding in an analogous way to cognitive Theory of Mind processing. Unfortunately, our lack of behavioural data

means that we cannot determine whether the mean amplitude of the P3 was associated with differences in emotion understanding abilities in the task.

Our lack of findings may be related to the nature of the paradigm. The P3 effect has been demonstrated in electrodes over the Temporo-Parietal Junction (TPJ), which is complementary to findings of TPJ activation during belief-reasoning tasks using fMRI (e.g. Saxe & Kanwisher, 2003; Sommer et al., 2007). Geangu and colleagues (2013) similarly found a P3, but also found no significant P3 effect of condition (true-belief versus false-belief) in their study of cognitive ToM. They relate this to the differences involved in their passive task, compared to tasks requiring an active response (such as in Meinhardt et al., 2011). The authors posit that there are differential effects of attentional mechanisms, active questions, and explicit (rather than implicit) judgements about mental states (all postulated to involve activation at the TPJ), which are present in 'active' paradigms, and not within their passive task. For example, Meinhardt and colleagues (2011) suggested that, in accordance with the theory that the TPJ is involved in the attentional system (e.g. Mitchell, 2008), the P3 component represents an active shift in attention; shifting attention from the protagonist's behaviour to the protagonist's mental representation (e.g. Corbetta, Patel & Shulman, 2008). This may not happen in passive paradigms. Consequently, the lack of P3 effect in the present task, may similarly relate to the passive nature of the paradigm used. However, the fact that an overall P3 was demonstrated suggests that the children were attending to the stimuli.

Moreover, Liu, Meltzoff and colleagues (2009) found activation over TPJ scalp electrodes for belief processing, but not for desire processing, in adults. Hence, the P3 may also relate specifically to belief processing (not required in our task), rather than ToM more generally. Interestingly, Bowman and colleagues (2012) used the same ToM task as Liu, Meltzoff and colleagues (2009), but tested seven- and 8-year-old children. They found a difference between belief and desire reasoning in neural activation over right-posterior electrodes, but only for children

who ‘passed’ the ToM tasks. Accordingly, it may also be that in our total sample, some children did not understand which emotion the characters were supposed to be feeling (and therefore, had there been a behavioural component, would not have ‘passed’ the task). This is consistent with Liu, Sabbagh and colleagues (2009), who found an LPP effect associated with ToM reasoning, only in adults and children who could accurately process ToM tasks. Thus it may be that if we had a behavioural measure, and repeated the analysis with only the children who understood the task, a P3 congruence effect may have been present. This evidence contrasts somewhat with imaging studies finding TPJ activation in both affective and cognitive ToM tasks (Sebastian et al., 2012). However, the caveat of ERP source localisation applies; due to poor spatial resolution associated with ERP analysis, we cannot conclude whether the P3 component does relate to TPJ activation.

N400

Our data demonstrated a potential N400, however it was noisy, and there were no significant differences between congruent and incongruent scenes, suggesting that it was not related to violation of expectation. Although the N400 has been demonstrated in numerous studies involving violation of expectation (Kutas & Federmeier, 2011), the vast majority of studies employed language-based paradigms (Ibanez et al., 2012). The one study which found an N400 in relation to a visual emotion-based violation of expectation (Goto et al., 2013) had a number of flaws. For example, visual inspection of their data demonstrates that it contains a significant amount of noise (with the figures already having being smoothed for presentation purposes), and the N400 effect does not appear to be distinguishable from effects at other time-points. Additionally, the effect was not seen in European-American participants. These issues therefore make the validity of their significant N400 effect somewhat unclear. It may therefore be that the N400 is related to language processes, and that our study reflected abilities unrelated to language. It

would be interesting to have controlled for language abilities within the present study, especially given that emotion understanding and language have been shown to correlate (e.g. Pons, Lawson, Harris & De Rosnay, 2003), and this may be a useful direction for future research.

Relationship with socio-emotional competence

Weimer, Sallquist and Bolnick (2012) suggested that research was needed to "examine links between children's false-belief knowledge…emotion understanding, and social relationships'' (p. 296). Our study found no significant relationship between neural correlates of emotion understanding (i.e. the LPP congruence effect) and social competence. This may be for a number of reasons; firstly, the sample size is relatively small, and accordingly the study may simply be underpowered to detect a significant effect. This seems plausible, given that past research has found associations between emotional ToM and social competence (e.g. Bosacki & Wilde-Astington, 1999). It may also have been related to our choice of measure. Bruneau-Bherer and colleagues (2012) cite a number of difficulties within the measurement of social cognition in children. These include: a lack of external validity, and thus generalisability to real-life scenarios (as discussed previously), a lack of coherence regarding definitions of social competence, and lack of norms/small sample size associated with measures. They state that "the association between performance in experimental settings and everyday social functioning, or between performance in an experimental setting and questionnaires assessing social skills, is modest at best'' (Bruneau-Bherer et al., p. 139). The measure used to assess social competence in this research (the Social Competence Scale – Parent Version; Conduct Problems Prevention Group, 1995), was in part chosen due to its length and ease of administration. It has been previously validated with large sample size, and against a control group (Corrigan,

2003), but, as far as we are aware, it has not been associated with task performance in an experimental setting.

It could also be that this facet of emotion understanding is not directly related to social competence. Although numerous studies have demonstrated a link between children's ability to understand emotions in context, and their social competence (e.g. Caputi et al., 2012; Hubbard & Coie, 1994), no research to date has studied this in relation to the specific task used in this research. Hughes and Leekam (2004) discussed a similar paradox in the contrast between 3-year-olds' inability to pass false-belief tasks, but success at social interactions in everyday life. They comment that "this contrast leads to the question of whether, under this formal definition, 'theory of mind' has any fundamental significance for children's social competence" (p. 591). They propose that this may be a reason to widen the definition of theory of mind, for example to cover perception of emotion. Perhaps the specific aspect of emotion understanding within this task is not related to social competence? Additionally, it may be that this task is not assessing emotion processing, but rather important aspects of the information processing required for emotion understanding (such as attention). Individual variation in these aspects may be unrelated to competence in emotion understanding.

Finally, there may have been a ceiling effect operating, meaning that all of the children were easily able to understand the emotions within the task. Previous research has demonstrated that 3-year-old children are able to determine whether a character in a story will feel happy or sad, depending on the situation, and can understand external causes of emotions (e.g. Cutting & Dunn, 1999; Salmon et al., 2013; Yuill & Pearson, 1998), therefore our sample, at six-years-old, may have all found the task relatively easy. However, there were no such ceiling effects within the studies on which the paradigm is based, even though the children within those studies were older (Steele et al., 1999, 2008). Additionally, Sebastian and colleagues (2012) found that adolescents and adults were less accurate at an

affective ToM task than they were on a cognitive ToM task; they suggest, therefore, that affective ToM is more difficult than cognitive ToM. Thus, although a ceiling effect within the EEG task is possible, it seems unlikely.

Ceiling effects were not seen within the measures of social competence, but there was limited range within the scores. In particular, the Social Competence Scale (Conduct Problems Prevention Group, 1995) score is calculated by computing a mean; the resulting scores thus varied between 1.7 – 3.9. This may not be enough variation to detect a relationship between this and the LPP congruence effect. However, a similarly non-significant result was obtained when the total score was instead used, which demonstrated greater variation.

A celling effect within the EEG task (i.e. a potential lack of variation in the children's level of understanding of the emotional scenes) may also explain the lack of association between age/Executive Function (EF), and the LPP congruency effect, which may have been expected from past research (e.g. Aboulafia-Brakha et al., 2011; Denham et al., 2012; Vetter, Altgassen, Phillips, Mahy & Kliegel, 2013). Conversely, it could be argued that although cognitive ToM tasks implicitly require EF abilities, as a child must inhibit their own perception of reality in order to process another person's perception of reality, this is not necessarily the case with our emotion understanding task; a child could base their prediction of the emotional consequence using their knowledge of how they themselves would react. Thus there may be alternative explanations to a ceiling effect to explicate the lack of association with EF.

Relationship with attachment

Preliminary analyses showed no relationship between the LPP congruence effect and attachment security, although the study was underpowered to detect such an effect; there were only seven insecurely attached children within the sample. Small numbers of children with insecure attachments may be common within attachment

research, and thus Type II errors are likely (Fraley & Waller, 1998). The use of a dimensional measure (such as the Attachment Q-Sort; Waters & Deane, 1985), rather than a categorical measure, may be preferable in future research.

Limitations

The passive nature of this task is both a strength and a limitation. Whilst a lack of response reduces the risk of movement artefacts, and allows for the efficient presentation of sufficient numbers of stimuli for ERP analysis in young children, it also means that no behavioural data was collected directly from the task. We thus had no objective measurement of emotion understanding. This would have enabled further analysis into issues regarding potential ceiling effects, or differences in the ERPs of children who understood the task, versus children who did not. It would thus be interesting for future research to associate task performance with another measure of emotion understanding (such as the widely used Affective Perspective Taking Task; Denham, 1986), as well as perhaps implementing a response option into the main task itself.

A further limitation relates to the use of ERP methodology. Whilst EEG has high temporal resolution, it is limited by low spatial resolution. Consequently, scalp distribution of activity does not allow direct inference of the localisation of underlying neural activity. Studies using fMRI, MEG, or ERP source localisation procedures are thus needed to relate these processes to brain regions.

Finally, as previously stated, this study was underpowered to detect a relationship between attachment status and emotion understanding abilities. A larger sample size is therefore required.

Implications

The primary aim of this research was to create a paradigm suitable for examining the neural correlates (specifically ERPs) of emotion understanding in young

children. The results demonstrate that it is possible to obtain ERPs related to emotion understanding from a passive viewing paradigm, as in recent adult studies of cognitive ToM (e.g. Geangu et al., 2013). This paradigm has a number of benefits; firstly, as no response was needed, there was less movement inherent within the task, and thus fewer artefacts. Consequently, the data obtained were relatively clean, and we were able to keep a larger number of trials than is common within similar ERP studies of young children (e.g. Liu, Sabbagh et al., 2009). As a result, this paradigm has proven to be particularly suitable for use within the paediatric population.

Furthermore, researchers have often cited the lack of 'realism' in tasks investigating aspects of social cognition, including emotion understanding (e.g. Bruneau-Bherer, Achim & Jackson, 2012, p. 139). This task has arguably higher external validity in comparison to other tasks of emotion understanding, as it looks at emotions related to context. This is in contrast to tasks which involve, for example, inferring mental states from facial expressions alone (e.g. the 'Reading the Mind in the Eyes' task; Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001), or superimposing large faces on unrelated background scenes (e.g. Goto et al., 2013). Consequently, we might expect it to be more related to emotion understanding abilities in 'real life', where context plays a key role in one's understanding of an emotion (e.g. Barrett, Lindquist & Gendron, 2007).

The effect within the Late Positive Potential has previously been seen within many Theory of Mind studies (Meinhardt et al., 2011). This therefore suggests that similar processes are involved in understanding other people's emotions in context, and understanding other people's thoughts in context. In some ways, this is intuitive; both implicitly involve understanding another's mind (e.g. Dunn, 1995). However, there is significant debate regarding both the extent to which cognitive processes involved in ToM and emotion understanding overlap, and the timelines of their development. For example, young children's ability to understand the external

causes of emotions has been positively correlated with knowledge of false-beliefs (Guajardo, Snyder & Petersen, 2009). Longitudinally, research suggests that in very young children (3-4-year-olds) emotion understanding both develops earlier than cognitive ToM, and that early emotion understanding is a predictor for later cognitive ToM abilities (O'Brien et al., 2011). However, cross-sectional studies of older children, using more complex reasoning tasks, have found that 4-6-year-olds are better at predicting another person's actions, as opposed to their feelings (de Rosnay, Pons, Harris & Morrell, 2004). Imaging and lesion studies also suggest that slightly different areas are involved within emotional ToM and cognitive ToM tasks (e.g. Poletti, Enrici & Adenzato, 2012); the medial Pre-Frontal Cortex (mPFC) is particularly implicated in emotional ToM (e.g. Leopold et al., 2012; Sebastian et al., 2012).

O'Brien et al (2011) state that 'there remains a lack of clear empirical evidence … on how the two constructs [emotion understanding and Theory of Mind] are related over time in development'' (p.1075). Weimer and colleagues (2012) echo this sentiment; "further research is needed in order to understand the relation between these distinct aspects of social cognition and to clarify how young children's understanding of belief relates to both specific and broad emotion-understanding abilities" (p. 280). We would thus anticipate that our task could be used alongside ERP tasks of ToM, to better understand the relationship between the neural correlates of these abilities.

An improved understanding of the relationship between emotion understanding and theory of mind would allow focus on interventions targeted at improving emotion and social competence and decreasing behaviour problems and psychopathology, such as the 'emotion-based prevention program' investigated by Izard and colleagues (2008).

Conclusions and avenues for further research

In summary, this is the first research of its kind to successfully investigate the neural correlates of emotion understanding in young children. Initial results suggest that similar neural processes are involved when undertaking emotion understanding and cognitive ToM tasks. Specifically, we found the presence of a Late Positive Potential (LPP), associated with understanding emotions in context.

Future research should employ both emotion understanding and cognitive ToM tasks, to further understand the neural processes underlying these related concepts. Additionally, imaging studies that are able to localise the neural responses would be beneficial, in order to ascertain whether these facets of ToM recruit similar brain regions. Furthermore, measures of language ability, and well-validated measures of social competence would support research into how these abilities relate to the neural correlates of emotion understanding. As this is the only study to investigate ERPs related to emotion understanding in young children, replication would strengthen the reliability and validity of the findings (Button et al., 2013).

In addition to enhancing knowledge of the development of emotion understanding in typical development, there are numerous potential avenues for clinically relevant research using this paradigm. In particular, the paradigm could prove useful for investigating the neural correlates of emotion understanding in clinical populations known to have deficits in this area, such as children with Autism Spectrum Disorders (ASD; Golan et al., 2008), Attention-Deficit Hyperactivity Disorder (ADHD; e.g. Da Fonseca et al., 2009), and maltreated children (Luke & Banerjee, 2012). For example, it would be interesting to compare the neural correlates associated with this task in children with neurodevelopmental disorders, with those found in typically developing populations. We may hypothesise that children known to have a deficit in emotion understanding would demonstrate a smaller effect of congruency in the LPP, than those who find emotion understanding comparatively easier. Similar research investigating the neural correlates of emotion

recognition, as opposed to understanding, has demonstrated this type of effect. For example, Dawson, Carver, Meltzoff, Panagiotides, McPartland and Webb (2002) used an EEG paradigm to compare ERPs in three to four year old children with ASD, and typically-developing control children, when viewing faces. They found that whilst the typically developing children demonstrated differences in ERP amplitudes when viewing photographs of their mother's face compared to an unfamiliar face, children with ASD did not show this effect.

Studies have also used ERPs as predictors of likelihood of future impairment. For example, Guttorm, Leppänen, Poikkeus, Eklund, Lyytinen & Lyytinen (2005), found differing patterns of ERPs in infants at risk of familial dyslexia, compared to a control group, which were also associated with later language and neurocognitive outcomes. In a similar way, the present paradigm could potentially be used to identify children at risk of developing later difficulties in emotion understanding, and who may benefit from intervention in the area.

It is also possible that this paradigm could be used as an outcome measure; the task could be given prior to, and following an intervention designed to improve emotion understanding. For example, Bauminger (2002) developed an intervention designed to improve social-emotional understanding in children with autism. Again, we may expect that a larger LPP congruency effect would be demonstrated post-intervention compared to pre-intervention. A review of ERPs in clinical research (Duncan et al., 2009) stated that 'the relationships between ERP measures and clinical interventions for developmental disorders have barely begun to be explored'. This is therefore an exciting new opportunity for advances in our understanding of the neural mechanisms of therapeutic interventions.

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Part 3: Critical Appraisal

External validity in EEG research

As a psychologist interested both in development and in neuroscience, this research appealed on a number of levels. My final placement within a paediatric neuropsychology service has demonstrated the importance of brain-behaviour relationships; that is to say that it is the impact of brain processes on *behaviour* that is important. I was therefore keen for this research to translate into behaviour in the 'real-world'. However, there were a number of difficulties faced in achieving this aim. These related primarily to the development of the paradigm, selection of measures and methodological issues endemic to EEG research.

Developing an externally valid paradigm

As expected for research that has a primary aim of developing a paradigm, a number of hurdles had to be overcome within the development phase. EEG research typically isolates components of an aspect of cognition. Within research investigating facets related to emotion understanding, this has often meant that studies have separated out small aspects of emotion understanding. For example, the 'Reading the Mind in the Eyes' task (Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001) focuses on emotion recognition. Conversely, 'real-world' emotion understanding involves piecing a number of cues together, and understanding another's emotion in relation to a context (e.g. Zaki & Ochsner, 2012). Therefore, we set out to develop a paradigm that used context, and that was as close to emotion understanding in real-world situations as possible.

The largest issues in designing such a paradigm came hand-in-hand with our chosen participant population - 6-year-old children. As with most neurophysiological methodologies, EEG requires that the participant sits extremely still, so as to minimise noise within the data. Unfortunately, this is not an ability for which 6-year-olds are well known. Thus the aim of developing an externally-valid paradigm had to be compromised with the inherent difficulties of EEG research in this population.

To obtain Event Related Potentials (ERPs), a number of trials have to be completed and neural responses then averaged. This means that ERP studies can quickly become rather boring; a feature that we were keen to minimise in our study. An engaging task would be more likely to hold the attention of a 6-year-old child and stop them wriggling quite so much. However, even the most engaging task would be unlikely to hold the attention of a young child for longer than 20 minutes. This issue was compounded by the fact that the children were also completing a task for a second study. We thus faced the challenge of creating an externally-valid, reasonably quick, engaging task, during which a child would sit still enough for clean data to be collected.

We initially started with the researcher reading out the text of the story; however, the children would turn towards her (even with constant prompts not to) and thus the data were too noisy. The same occurred when the researcher asked the participant what the cartoon child would be thinking. We also considered the possibility of having two response options that the child could click from; a happy and sad face, as in Steele and colleagues (1999, 2008) and Goto and colleagues (2013). We made the decision that this would extend the time taken to complete the task and thus was not feasible in this setting. In addition, the extra movement occurring whilst the child moves the mouse would again increase the noisiness of the data.

The decision instead to make this task a passive viewing task was not taken lightly. Adding some sort of response has the obvious advantage of collecting behavioural data. It would also enable behavioural data more closely related to the EEG data to be correlated with attachment status. Thus, this would have enhanced the possibility of finding a relationship between neural activity and behaviour, and consequently the external validity of the ERP results.

Goto, Yee, Lowenberg and Lewis (2013) used a similar paradigm which successfully integrated behavioural data. They used scenes from the International

Affective Pictures System (Lang, Bradley & Cuthbert, 2008), superimposed with emotional faces selected from Matsumoto and Ekman (1989). Participants had to press one button if the face they viewed was happy, and another if it was sad. Accuracy and reaction time were then recorded. Although the scenes used would not have been suitable for young children, this type of behavioural data would be a useful addition to future research of this kind. However, Goto and colleagues' (2013) task appeared to have little in the way of face validity or external validity. In their task, large faces were simply superimposed on the background scene. Conversely, in our task, the faces were *part* of the scene, as they would be in real life scenarios. Thus it could be argued that our task had higher external validity.

Behavioural data was similarly collected by Meinhardt and colleagues (2011) in their study of ERPs related to Theory of Mind in children. In their study, children were shown film clips of false-belief eliciting stimuli. A cartoon figure was shown to place two animals in two different boxes; they then stand in front of the boxes and the animals are seen to move to different boxes. The participants are then asked a reality question – 'where is this animal really?' and a Theory of Mind question 'where does the person think this animal is?'. The participants either answered the questions verbally or by pointing. The reality questions acted as control questions, in order to ensure that the participants were paying attention. If a participant did not correctly answer the reality control question, then they were presented with the stimulus again. We had no such method in our study of ensuring the children were both paying attention and understood the scenes. Again, such a paradigm would have been helpful for our study, but increases the length of the study and requires that children move and/or talk in order to respond, which may have increased noise within the data. However, the presence of a P3 ERP suggests that they were attending to the stimuli.

The final paradigm achieved was thus a compromise between making the task externally valid and as engaging as possible, whilst keeping it short and

minimising the impact of noise on the data. In general, it worked well; children appeared to enjoy it and the data was of a fair standard. There were a couple of shortfalls, however, which would be useful to address in future research. One arose because of the randomisation of the stimuli. The task crashed on a couple of occasions, but because the stimuli were fully randomised, we could not start blocks again, as the same stimuli may have been presented. Given that the point of the study was that children would have to make inferences about emotional states, the results would be redundant if the child had seen the emotional state previously. Therefore, pseudo-randomisation would be helpful in future studies.

A shortfall within the research was that it could be argued that parts of the development phase were missed out. We had originally planned to pilot the task with adults and then with a small number of 6-year-old children, but due to issues beyond our control, we did not have the time to do this. As this did not happen, this research can be considered to be in itself a pilot study. It was interesting to note though, that a couple of children tested were unable to stay quiet and instead chose to provide a running commentary of the task to the researcher. In particular, they would voice their disagreement when the facial expression was incongruent with the scene. Many others (including some of the parents) commented in the break that they did not understand the cartoon child's expression for some scenes. This is encouraging and suggests that the participants did understand the scenes and that the expressions were appropriately assigned. Again, the lack of behavioural data means that we cannot conclusively say that the children did understand the task, but the significant ERP findings related to the congruence effect, along with this qualitative information, are good indications that they did.

It would have been extremely useful to have trialled each of the scenarios with both adults and children; firstly this would have allowed us to refine the scenarios and use only those which were understood by the majority of people. However, we were keen for the scenarios not to be 'too' easy, as this would be likely

to create a ceiling effect and thus minimise the likelihood of finding any differences in the attachment groups (as indeed we found). Secondly, this would have allowed us to see whether an N400/LPP was produced. However, given that the point of power calculations is to give an estimate of the likely number of participants needed to observe an effect, if an N400/LPP was not seen in a small pilot sample, this does not mean that one would not be produced across a larger sample.

Analysis

Creating an externally valid paradigm led to difficulties in the process of analysis. Button and colleagues (2013) reflect on this issue of 'vibration of effect sizes' in relation to small, underpowered studies in neuroscience. They explain that there are numerous differences in the methodologies and analysis techniques employed by neuroscience researchers, even when using the same overarching techniques. These differing methodologies will thus produce differing results and corresponding effect sizes. One such difference in methodologies of ERP studies is the issue of electrode selection; as each electrode will relate to different neural activity, the selection of electrodes for analysis has a major impact on the results of the study. However, there are no explicit rules for electrode selection (Ibanez and colleagues, 2012). This is particularly challenging for the present study as no such research has been carried out before, and thus determining 'Regions of Interest' was not easy. The study was partly exploratory and as such we examined a number of different electrodes. However, as in any psychological research, ERP analysis is based on statistical techniques, and therefore are subject to inflation of Type I error if numerous tests are used. The same is true for other neurophysiological (non-ERP) research, as discussed by Button and colleagues (2013). Thus, ideally, specific Regions of Interest would be documented before analysis.

We did identify Regions of Interest prior to the beginning of the research, however this proved difficult due lack of past research on the subject of the neural

correlates of emotion understanding. The problem is compounded by a lack of clarity in the literature regarding the precise mechanisms and component processes involved in emotion understanding. Even when taking a narrow view of emotion understanding as the ability to make sense of another person's emotions based upon contextual information (e.g. Weimer, Sallquist & Bolnick, 2012), this ability is based upon other skills. For example, Shamay-Tsoory, Harari, Aharon-Peretz and Levkovitz (2010) suggest that cognitive Theory of Mind, cognitive empathy and emotional empathy are prerequisites for emotional Theory of Mind (i.e. emotion understanding). Each of these may be related to separate neural activation, and lesion studies have demonstrated that they are indeed separable abilities within defined neural areas (see Sebastian et al., 2012 for a review). Therefore, we might expect that our paradigm may have caused neural activation related to all of these aspects of emotion understanding.

Figure 1. The relationship between emotion understanding ('affective Theory of Mind - ToM'), cognitive ToM and empathy, from Shamay-Tsoory, Harari, Aharon-Peretz & Levkovitz (2010).

Although early research using simplified stimuli may have activated only one of these systems, more recent naturalistic research such as ours (which we would argue has greater external validity), likely activates a number, and each interacts with the other (Zaki & Ochsner, 2012). For example, the task employed in this study

involved not only hypothesising about another's internal emotional state, but also emotion recognition. It also required some level of cognitive Theory of Mind, regarding another's desires, beliefs or intentions. Therefore, we could have investigated electrodes linked to any or all of these factors. However, this would have massively inflated the chances of a Type I error.

The final choice of electrodes was based on the studies with paradigms most similar to the present design, however there were very few studies on which to base these on. Even within one aspect of emotion understanding, such as cognitive Theory of Mind, regions of interest and selected electrodes vary, and they can be different for different populations (for example Meinhardt and colleagues, 2011, found different regions of activation in children compared to adults). As there are few studies within this area, selecting electrodes/Regions of interest was particularly difficult. Consequently, it may have been that had different Regions of Interest been chosen, different results would have been demonstrated. Thus, to summarise, creating an externally valid paradigm created difficulties with interpretation.

Defining emotion understanding: Literature review and measure selection

Definitions of social and emotional competence vary widely, and this created problems in defining both the scope and search terms for the literature review, and issues in measure selection within the empirical paper. As we did not collect behavioural data from the EEG task, for reasons outlined previously, it was important to obtain a good measure of social-emotional competence, again, so that we could relate brain activity to differences in behaviour. As definitions of social-emotional competence vary, so too do measures of the concept. We wanted a measure that showed high external validity; i.e. that was related to meaningful differences in behaviour, as per Foster and Richey's (1979) behavioural definition of 'socially competent behaviour' as "those responses, which, within a given situation, prove effective, or… maximise the probability of producing, maintaining or

enhancing positive effects for the interactor" (p. 626). As with other aspects of the study, the measure chosen represents a compromise between quality and quantity. The questionnaires needed to be as short as possible, particularly as parents were already completing a large battery of longer questionnaires as part of the second research study. Shorter questionnaires also have the benefit of being easier to answer and therefore parents were less likely to make errors in their completion.

Regrettably, the well-validated and reliable parent measures of social-emotional competence were long and/or costly. However, we chose our primary measure (the Social Competence Scale; Conduct Problems Prevention Group, 1995; Appendix G), on the basis of high face validity; it appeared to report on meaningful social behaviour, as well as being freely available, quick to administer and easy to complete. Unfortunately, the results from this measure were unrelated to ERPs from the task. As discussed within the main paper, this could be due to a number of reasons. Although finding a relationship between the EEG task and the measures of social-emotional competence would have increased our argument that our task shows good external validity, the fact that we did not find an effect does not suggest the opposite.

Similarly, obtaining a meaningful definition of emotion understanding was key to the literature review, and caused some difficulties in defining the search terms. Good external validity means that the results are generaliseable to the external world. Arguably, creating clear-cut distinctions between highly related concepts is somewhat artificial, and therefore would reduce the external validity of the findings. We thus set out for the scope of the search to be as broad as possible.

For example, cognitive Theory of Mind tasks are arguable not strictly tasks of emotion understanding. However, there is huge potential overlap between emotion understanding and cognitive Theory of Mind; both involve an understanding of another's mental state, the difference being that one is cognitive and the other emotional. Hughes and Leekam (2004) cite numerous research studies that

demonstrate a link between various facets of social – emotional understanding and false-belief comprehension. These overlaps led to the decision that tasks of cognitive Theory of Mind should be included within the literature review. In practice, this meant that our reviewed spanned a large range of studies. Although this increases our confidence that we have captured the relevant papers within the area, it also meant that the review needed to tie together information from what turned out to be disparate studies with somewhat contradictory findings, in a meaningful way. It might have been easier, for example, to exclude studies that investigated purely cognitive Theory of Mind. Again, attempting to increase external validity led to difficulties with interpretation of the results.

Conclusion

To summarise, the main issues reported in this appraisal centre around the difficulties of designing research with high external validity. As with many aspects of research this is a balancing act. Increasing external validity improves generalisability to the outside world. However it can lead to considerable difficulties interpreting results, especially when considering a wide-reaching concept such as emotion understanding. Only good replication will enable researchers to be more confident that any significant results are the results of a true effect, and not spurious findings. Thus, replication of our study is crucial, especially given that at present, this is the only study of its kind.

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Appendix A: Trainee contributions to the joint project

- Study design, including EEG task development and measure selection, was undertaken individually.
- Applications for ethical approval, development of consent forms and information leaflets, overall study protocol, recruitment, testing and data entry were undertaken jointly.
- Data analysis and write-ups were undertaken individually.

Appendix B: Initial participant contact letter

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12 Maresfield Gardens, London, NW3 5SU
www.annafreud.org

Caring
for young
minds

Anna Freud Centre

Dear Parent,

We are writing from the Anna Freud Centre's Development Neuroscience Unit. We would like to invite your child to take part in a new research study. Our study is aiming to investigate how children develop their abilities to control their actions and to understand social situations. Taking part will involve a visit to the Anna Freud Centre in Hampstead for about 2 hours. This visit can be arranged for a time to suit you.

We are contacting you because four years ago you took part in a study at the Anna Freud Centre. When you took part in that study, the researchers gathered information about the relationship between your child and their caregiver. We are inviting you to take part in a study which is following up on this previous research. Being able to follow children over time is very useful to psychology researchers, as it enables us to see how experiences earlier in life might have contributed to their skills and abilities when they are older.

Before you and your child decide whether you would like to take part, it is important for you to know why the research is being done and what it will involve. We will give you a quick phone call to see if you are interested in hearing more about the study in the next week. We have also enclosed an information leaflet, which describes our research in more detail. Please do not hesitate to contact us if you would like to discuss the study further in the meantime.

Many thanks for taking the time to read this. We look forward to hearing from you,

Yours faithfully,

Samantha Taylor-Colles Sophie Bennett Sarah Carman

Appendix C: Participant information sheet

PARENT/GUARDIAN INFORMATION SHEET AND CONSENT FORM FOR CHILDREN AGED 4-6YRS

The Development of Controlling Actions and Understanding Social Situations

We are researchers at the Anna Freud Centre's Developmental Neuroscience Unit and UCL who are interested in child development. We would like to invite your child to take part in our research study. Before you and your child decide whether you would like to take part, it is important for you to know why the research is being done and what it will involve. Please take time to read this information sheet carefully and discuss it with others if you wish. If there is anything that is not clear, or if you would like more information, please do not hesitate to contact Sarah Carman or Sophie Bennett on 020 7794 2313.

Anna Freud Centre

The aim of the study

We are investigating how children develop the ability to control their behaviour and understand social situations.

Why is the study being done?

We know from studies that have followed children over a number of years that learning to control actions and to understand social situations is an important part of a child's development. How these abilities develop is different for each individual child, and there are many factors that are thought to contribute to the process. We are interested in finding out more about what happens in the brain when children try to make sense of social situations and when they try to control their actions. We are also interested in how these abilities are related to their earlier development, such as their relationships with their carers and their temperament.

We hope that this will give us a better understanding of how children learn to control their actions and understand social situations, including new information about what is happening in their brains when they think about these things. We also hope that in the future, this understanding will eventually help us understand how developmental disorders and mental health problems arise later in life, and will help us to treat those who do suffer from these problems more effectively.

Why have we been asked to take part?

We are contacting you because several years ago you took part in a study at the Anna Freud Centre. When you took part in that study, the researchers gathered information about your child's development and about parent-child interactions. We are inviting you to take part in a study which is following up on this previous research. Being able to follow children over time is very useful to psychology researchers, as it enables us to see how earlier development relates to skills and abilities later in life.

What will happen if we take part?

If you agree to take part, we will invite you and your child to come to the Anna Freud centre, at a time that is convenient for you. The whole thing should take around an hour and a half to two hours. We will reimburse your travel expenses and offer a £5 voucher as a thank you for giving up your time.

Whilst you are here, we will ask your child to play some games on the computer while we measure what is happening in their brain using EEG technology. EEG is a safe and non-invasive method of measuring tiny changes in the levels of electrical activity produced by the brain when we think. We will ask your child to wear a net on

their head, a bit like the picture, whilst they play two computer games. In total, this part should probably take no more than about forty minutes, although it can take some time to put the net on and get ready to play the games.

We will also ask your child to play a game with some toy people characters. We won't ask your child to wear the EEG net whilst they are playing this game. We will ask them to act out different stories with the characters, to look at how they think about different social situations. This should take no more than half an hour. This game will be filmed, so that we can review and rate your child's responses. The data will be transferred from the camera and stored securely on the Anna Freud Centre computer system.

Anna Freud Centre

Whilst you are at the Anna Freud centre we will ask you to complete some questionnaires about your child. Please talk about the study with your child. Sarah and Sophie (the researchers) will also make sure that your child understands what he/she will be doing and give him/her an opportunity to ask any questions that he/she may have.

Are there any risks of discomforts?
We do not envisage that the things we will ask your child to do will cause any discomfort. EEG is used very commonly in research with children and is entirely safe and non-invasive. Most children don't mind wearing the net at all, but we will stop if your child is uncomfortable. This study has been approved by the UCL Research Ethics committee.

Does my child have to take part in this study?
It is up to you and your child whether or not you take part in this study. If you do decide to take part, you will be asked to sign a consent form. If you decide now, or at a later date, that you do not wish to participate in this research you are free to withdraw at any time without giving a reason. Even if you are happy for your child to take part, he or she will still decide for himself. It will be explained to your child that he/she can choose to withdraw from the study at any time, without giving a reason. We want to make sure that everyone is happy when taking part in our project.

Will information about my child's performance be available to anyone?
All information collected from you and your child during the course of this research will be kept strictly confidential, unless required by law.

Who will have access to the research records?
Only members of our research team will be able to look at the information we collect. The use of some types of personal information is safeguarded by the Data Protection Act of 1998 (DPA). The DPA places an obligation on those who record or use personal information, but also gives rights to people about whom information is held.

How to contact the researchers
If you would like to know more about this research, you can contact Sophie or Sarah on 020 7794 2313. If you prefer to email, you can contact Sophie on Sophie.Bennett.10@ucl.ac.uk or Sarah on Sarah.Carman.09@ucl.ac.uk.

Thank you for taking the time to read this information sheet

Appendix D: Participant consent form

Tel +44 (0)20 7794 2313
12 Maresfield Gardens, London, NW3 5SU
www.annafreud.org

Caring for young minds

Anna Freud Centre

The development of executive function and understanding social situations: An EEG study

Consent Form:

If Yes, please complete the following:

☐ I have read the Information Sheet and understand what the study involves

☐ I have had the opportunity to ask any questions I wish to ask.

☐ I consent to the processing of my personal information, and that of my child, for the purposes of this research study

☐ I consent to the researchers accessing and processing the data obtained in the previous study which myself and my child previously participated in, for the purposes of this research study.

☐ I consent to a videotape of my child being recorded whilst they undertake the 'Story Stems' Task. I understand that this video is being used solely for the purpose of data analysis and will be kept securely at the Anna Freud Centre in accordance with the provisions of the Data Protection Act 1998.

☐ I understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998

☐ I understand that I am free to withdraw my child from the study at any time without giving a reason.

☐ I understand that my child is free to withdraw from the study at any time without giving a reason.

☐ I give consent to be contacted directly by the research team in the future at the details given by me on this form.

☐ I have the names and telephone numbers of the research team in case I have any queries in the future.

☐ I agree that the research project named above has been explained to me to my satisfaction and I agree for my child to participate in the study.

Child's Name: _____ Parent's Name: _____

Signature: _____ Date: _____

Address: _____

_____

Telephone number: _____

Email: _____

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Appendix E: Full demographic information of sample

All demographics taken at phase 1 of the study (i.e. when children were 12 months old)

Mother's Ethnicity

Ethnicity	Frequency (% of EEG sample)
White British	13 (39.4)
British	7 (21.2)
White European	8 (24.2)
Mixed	2 (6.1)
Anglo Chinese	1 (3.0)
Anglo Indian	1 (3.0)
White Other	2 (6.1)

Mother's Marital Status

Status	Frequency (% of EEG sample)
Married & Co-habiting	19 (57.6)
Unmarried & Co-habiting	12 (36.4)
Single	2 (6.1)

Mother's Level of Education

Level of Education	Frequency (% of EEG sample)
A-levels	2 (6.1)
NVQ	1 (3.0)
HNS	3 (9.1)
BA/Bsc	20 (60.6)
Masters/PhD	7 (21.2)

Household Income

Income (£ per annum)	Frequency (% of EEG sample)
Not stated	4 (12.1)
<10000	2 (6.1)
20000 – 30000	5 (15.2)
40000 – 50000	6 (18.2)
>50000	16 (48.5)

Appendix F: Transcript of EEG task instructions

You are going to be looking at some cartoons with boys and girls in. All I want you to do is listen to the story that I'm telling you and look at the pictures that go with the story.

At the end of the story I'm going to ask you what you think the boy or girl is thinking. I don't need you to tell me, I just want you to think about it in your head. Shall we have a practice?

Show the first one.

If they don't understand what they're supposed to be doing, explain again. It's important that they are not moving or talking when the emotion is 'revealed' so they need to know that they just need to think about it in their heads.

The number on the scene corresponds to the number of the scripts below.

Positive

1. **Apples**
   a) Alex wants an apple, but he can't reach
   b) Dad lifts him up and helps him reach an apple
   c) Now Alex has an apple, I wonder what he's feeling? Shall we see?

2. **Birthday Present**
   a) Adam is in a toy shop with his mum. He sees a teddy he likes
   b) It's Adam's birthday. He starts to unwrap a present and it's the same bear. I wonder how he's feeling? Shall we see?

3. **Book Shelf**
   a) Ben wants a book from the shelf, but he can't reach because it's on the top
b) Dad reaches the book down for Ben
   c) Ben has the book and starts to read it. I wonder how he's feeling? Shall we see?

4. **Crisps**
   a) It's break time at school and Anna, Adam and Penny are eating their snacks.
   b) oh no! Penny tripped and dropped her crisps
   c) Adam shares his crisps with Penny because she doesn't have any left. I wonder how she's feeling? Shall we see?

5. **Cut head**

a) Charlotte has cut her head
   b) Dad gives her a plaster to put on it
   c) Then they sit down on the sofa together . I wonder how Charlotte's feeling? Shall we see?

6. **Dad comes home**
   a) Amy is waiting for Dad to come home
   b) She sees him through the window
   c) Dad is home! I wonder how Amy is feeling?

7. **Flowers**
   a) Catherine has bought mum some flowers for her birthday
   b) she gives them to mum. I wonder how Catherine's feeling? Shall we see?

8. **Football**
   a) Tom and Emma are playing football
   b) Tom kicks the ball towards the goal
   c) Tom has scored a goal! I wonder how he's feeling? Shall we see?

9. **Gold Star**
   a) Olivia is working hard at school
   b) Her work is so good that her teacher gives her a gold star to say well done
   c) Olivia comes out of school and shows mum her gold star. I wonder how she's

feeling? Shall we see?

10. Jigsaw

a) Jack and Grace are doing a jigsaw together, there is a piece missing
b) Jack finds the missing piece and it fits! I wonder how he's feeling? Shall we see?

11. Joining game

a) Joshua is watching some other children at school playing a game. He is sitting alone on the bench
b) Oliver sees that Joshua is all by himself. He decides to ask Joshua to join in the game
c) Joshua is playing the game too now. I wonder how he's feeling? Shall we see?

12. Plant

a) Jessica has planted a seed with mum. She waters it to make it grow.
b) Jessica keeps watering it, but four weeks later it still hasn't grown!
c) Then in three more weeks, the seed has started to grow! I wonder how Jessica is feeling? Shall we see?

13. Race

a) Harry is lining up for a race at sports day
b) He is coming first, I wonder how he is feeling? Shall we see?

14. Rain

a) Sam wants to play outside, but he looks outside and it's raining.
b) He decides to put on welly boots
c) He goes outside and plays in the puddles. I wonder how Sam is feeling? Shall we see?

15. Home time

a) George is at school. It's nearly time to go home
b) Now it is home time, George picks up his bag and coat
c) George goes to meet with Dad outside. I wonder how George is feeling? Shall we see?

16. Skates

a) Liz is learning to rollerskate. At first she needs to hold mum's hand because it is difficult and she feels a bit wobbly.
b) But after some practice, she lets go of mum's hand and skates really fast. I wonder how Liz is feeling? Shall we see?

17. Savings

a) Jess is saving up for a new toy. She puts her birthday money into her piggy bank
b) After a while, Jess decides to see how much money she has. She thinks she has enough for her toy now.
c) Jess does have enough money, so she goes to the toy shop to buy her toy. I wonder how Jess is feeling? Shall we see?

18. Two player game

a) Jill is playing with her dolls. There are two dolls but she doesn't have a friend to play with.
b) Then Jill's brother asks if he can play
c) Jill lets her brother play. I wonder how Jill is feeling? Shall we see?

19. Netball

a) Emma is watching her friends play netball.
b) Her friend Kate scores a goal. I wonder how Emma is feeling now? Shall we see?

20. Coin

a) Ollie is walking home from school

b) He spots something in the ground
c) It's a gold shiny coin! I wonder how Ollie is feeling? Shall we see?

Negative

21.Bike
a) William is cycling
b) Oh no! He's hit a rock and fallen off! I wonder how he's feeling? Shall we see?

22. Biscuits
a) Daniel wants a biscuit, but dad tells him he can't have one until after dinner
b) Daniel decides to get one anyway, when his dad isn't looking
c) But Daniel comes back and catches boy getting a biscuit. I wonder how Daniel is feeling? Shall we see?

23. Broken dinosaur
a) Charlie and Emily are playing with their toy dinosaurs
b) Charlie has broken the dinosaur. I wonder how he's feeling? Shall we see?

24. Broken vase
a) Mum is watching Ellie put some flowers in a vase on the table
b) But when Ellie is reaching over, she knocks the vase and it smashes. I wonder how Ellie is feeling? Shall we see?

25. Building blocks
a) Katie and Megan are playing together. Their teacher brings them some blocks to play with
b) Katie and Megan try to build towers. Katie builds a really big one, but Megan is finding it more difficult. She can only manage to build a little tower.
c) Their teacher comes back and asks them to show her the towers they have built. Megan shows the teacher her smaller tower. I wonder how she is feeling? Shall we see?

26. Burnt cake
a) Jake is making a cake with his dad. They are stirring the mixture together.
b) Dad puts the cake into the oven to bake
c) Dad pulls the cake out of the oven, but it has burnt. I wonder how Jake is feeling? Shall we see?

27. Bus
a) Hannah is late for school. She is running for the school bus.
b) Oh no! Hannah has missed the bus. I wonder how she is feeling? Shall we see?

28. Dad leaving
a) Dad is leaving to go away with work. Amy says goodbye to him
b) Amy watches him from the window.
c) I wonder how Amy is feeling? Shall we see?

29. Negative Dinosaur
a) George wants to wear his dinosaur costume for school
b) He puts it on himself, but dad says he has to wear school uniform
c) George puts his school uniform on. I wonder how he's feeling? Shall we see?

30. Empty Juice
a) Luke has some juice. He puts it on the table whilst he goes to find his sandwiches.
b) But whilst he goes to find the sandwiches, Millie picks up the juice and drinks it
c) When Luke comes back for his juice, he finds that girl has already drunk it all. I wonder how he's feeling? Shall we see?

31. Football

a) Ryan and Freya are playing football
b) Ryan kicks the football but it goes over the fence.
c) The ball lands in the garden next door. I wonder how Ryan is feeling? Shall we see?

32. Homework

a) Daisy is watching TV with her brother.
b) Mum comes in and tells girl that she has to do her homework before she can watch TV.
c) So Daisy does her homework in the kitchen whilst her brother watches cartoons in the living room. I wonder how Daisy is feeling?

33. Ice cream

a) Holly is eating ice cream
b) Oh no! Holly has dropped her ice cream. I wonder how she's feeling? Shall we see?

34. Lost Balloon

a) Callum has a balloon. He got it from a birthday party.
b) But he lets go of the balloon by accident
c) The balloon flies into the sky and boy can't reach it. I wonder how Callum is feeling? Shall we see?

35. Lost dog

a) Joseph is walking his dog with his mum
b) The dog starts to run away
c) Joseph drops the lead and the dog runs away. I wonder how he is feeling? Shall we see?

36. Mum busy

a) Poppy is drawing on the floor of the kitchen. It's time for her baby sister's dinner.
b) Poppy finishes her drawing. She takes it to show mum.
c) She tried to show mum but mum is too busy feeding the baby. I wonder how poppy is feeling? Shall we see?

37. Mum on phone

a) Rebecca is painting a picture at school.
b) She is really pleased with her picture, so she takes it home to show mum
c) She tried to show mum, but mum is too busy on the phone to look. I wonder how Rebecca is feeling? Shall we see?

38. Mum sick

a) Bethany is playing on the floor when mum comes in and says she has a headache
b) Mum has to go to bed, so girl has to go upstairs to play. I wonder how Bethany is feeling? Shall we see?

39. Sandcastle

a) Liam is building a sandcastle.
b) He turns the bucket upside down
c) Then he lifts the bucket up. But the sandcastle breaks and falls down. I wonder how Liam is feeling? Shall we see?

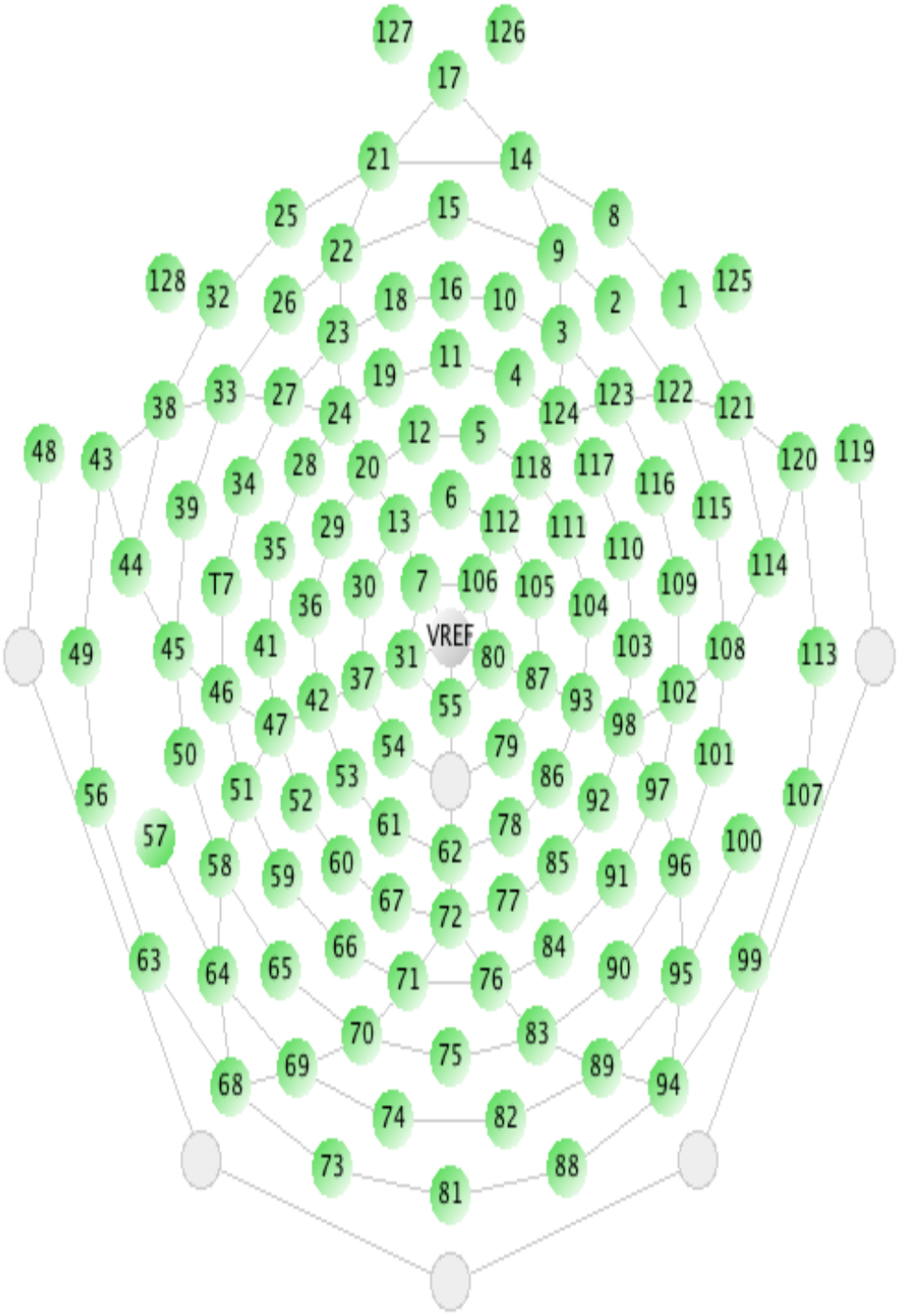
40. Spilt paint

a) Phoebe and Eleanor are painting pictures at school.
b) Phoebe goes to get some paper
c) Eleanor reaches for some more paint. But she knocks the paint over Phoebe's picture. I wonder how Eleanor is feeling? Shall we see?

Appendix G: Social Competence Scale – Parent Version

REMOVED DUE TO COPYRIGHT

Appendix H: Map of electrodes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Appendix Ia: Ethical approval (initial)

UCL RESEARCH ETHICS COMMITTEE
GRADUATE SCHOOL OFFICE

Professor Pasco Fearon
Research Department of Clinical, Educational and Health Psychology
UCL

2 March 2012

Dear Professor Fearon

Notification of Ethical Approval
Ethics Application: 3594/001: The development of executive function and social understanding: an EEG study

I am pleased to confirm thatin my capacity as Chair of the UCL Research Ethics Committeel have approved your study for the duration of the projecti.e. until October 2013.

Approval is subject to the following conditions:

1. You must seek Chair's approval for proposed amendments to the research for which this approval has been given. Ethical approval is specific to this project and must not be treated as applicable to research of a similar nature. Each research project is reviewed separately and if there are significant changes to the research protocol you should seek confirmation of continued ethical approval by completing the 'Amendment Approval Request Form'.

The form identified above can be accessed by logging on to the ethics website homepage: http://www.grad.ucl.ac.uk/ethics/ and clicking on the button marked 'Key Responsibilities of the Researcher Following Approval'.

2. It is your responsibility to report to the Committee any unanticipated problems or adverse events involving risks to participants or others. Both non-serious and serious adverse events must be reported.

   Reporting Non-Serious Adverse Events
   For non-serious adverse events you will need to inform Helen Dougal, Ethics Committee Administrator (ethics@ucl.ac.uk), within ten days of an adverse incident occurring and provide a full written report that should include any amendments to the participant information sheet and study protocol. The Chair or Vice-Chair of the Ethics Committee will confirm that the incident is non-serious and report to the Committee at the next meeting. The final view of the Committee will be communicated to you.

   Reporting Serious Adverse Events
   The Ethics Committee should be notified of all serious adverse events via the Ethics Committee Administrator immediately the incident occurs. Where the adverse incident is unexpected and serious, the Chair or Vice-Chair will decide whether the study should be terminated pending the opinion of an independent expert. The adverse event will be considered at the next Committee meeting and a decision will be made on the need to change the information leaflet and/or study protocol.

On completion of the research you must submit a brief report (a maximum of two sides of A4) of your findings/concluding comments to the Committee, which includes in particular issues relating to the ethical implications of the research.

With best wishes for the research.

Yours sincerely

Professor John Foreman
Chair of the UCL Research Ethics Committee

Cc: Sophie Bennett & Sarah Carman

UCL Research Ethics Committee, c/o The Graduate School, North Cloisters, Wilkins Building
University College London Gower Street London WC1E 6BT
Tel: +44 (0)20 7679 7844 Fax: +44 (0)20 7679 7043
ethics@ucl.ac.uk
www.ucl.ac.uk/gradschool

Appendix Ib: Ethical approval (amendment)

UCL RESEARCH ETHICS COMMITTEE

Amendment Approval Request Form

1	**Project ID Number:** 3594/001	**Name and Address of Principal Investigator:** Professor Pasco Fearon
2	**Project Title:** The Development of Executive Function and Social Understanding: An EEG Study	
3	**Type of Amendment/s (tick as appropriate)** ☒ Research procedure/protocol (including research instruments) ☐ Participant group ☐ Sponsorship/collaborators ☐ Extension to approval needed (extensions are given for one year) ☒ Information Sheet/s ☒ Consent form/s ☐ Other recruitment documents ☐ Principal researcher/medical supervisor* ☐ Other * *Additions to the research team other than the principal researcher, student supervisor and medical supervisor do not need to be submitted as amendments but a complete list should be available upon request.	
4	**Justification** (give the reasons why the amendment/s are needed) The original application included the Story Stems Assessment Protocol (SSAP) as part of the research assessment battery of tests. During the test the child is asked to finish short stories using toy characters. The SSAP has been validated with large numbers of children and standardised data of children's score is available, however in order to use this data the test must be administerd in the same, standardised way. This requires that the children be filmed and the tapes subsequently reviewed for rating and analysis. The SSAP therefore requires the use of video to ensure an accurate verbal and visual record of the child's responses, and enables researchers to review parts of the tape more than once to ensure accurate rating, which would not be possible were the rating to be conducted whilst the child were participating.	
5	**Details of Amendments** (provide full details of each amendment requested, state where the changes have been made and attach all amended and new documentation) In addition to the original proposed protocol, this requested amendment involves including videotaping participants during (and only during) the Story Stems Assessment Protocol task, in order that responses can be subsequently rated according to the assessment manual. Accordingly, the information leaflets and permission forms have been amended and are included along with this application.	
6	**Ethical Considerations** (insert details of any ethical issues raised by the proposed amendment/s) The filming of children raises issues of parental consent and data protection. These issue of informed consent to being filmed would be addressed through clear information on the information sheet, and a sentence referring explicitly to consent to being filmed on the consent form. With regards to data protection, the films would be stored securely on the Anna Freud Centre computer system, and deleted from the camera immediately after the data had been transferred.	
7	**Other Information** (provide any other information which you believe should be taken into account during ethical review of the proposed changes)	

Declaration (to be signed by the Principal Researcher)

- I confirm that the information in this form is accurate to the best of my knowledge and I take full responsibility for it.
- I consider that it would be reasonable for the proposed amendments to be implemented.
- For student projects I confirm that my supervisor has approved my proposed modifications.

Signature:

Date: 23/07/12

FOR OFFICE USE ONLY:

Amendments to the proposed protocol have been Approved by the Research Ethics Committee.

Signature of the REC Chair, Professor John Foreman: ..

Date: 15/8/2012