Exploring Children's Emotion Understanding through EEG Measurement of Neural Correlates and a Standard Emotion Understanding Task

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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

This thesis aimed to explore children's emotion understanding through an investigation of neural correlates and a review of the impact of emotion understanding ability on mental well-being.

Part one is a literature review of 38 papers measuring emotion understanding and mental health symptoms in children under 13 years old. Details of the studies are given and results are considered in terms of age group studied, emotion understanding task used and mental health symptom measurement. The evidence found was mixed, but suggests that early emotion understanding difficulties may be linked with externalising symptoms and may predict later mental health symptoms.

Part two presents an empirical paper detailing an electroencephalogram (EEG) task used to investigate neural correlates of emotion understanding in 5 to 8 year olds, which was compared with a self-report measure: the Test of Emotion Comprehension (TEC; Pons & Harris, 2000). Neural responses to congruent and incongruent, emotional and physical story outcomes were analysed and provided strong evidence for a neural index of emotion understanding. No significant correlation was found between the TEC score and neural components, which may reflect the brain-based measure's reduced reliance on language skills.

Part three provides a critical appraisal of the role of science in EEG and clinical psychology. Limitations and the role of interpretation in EEG are explored and the importance and implications of psychology being seen as a science are discussed. Finally, the value of combining findings from different methodologies to enhance understanding from a biopsychosocial perspective is outlined.

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Part 1: Literature Review

Exploring the Relationship between Emotion Understanding and Mental Health Symptoms in Young Children

Abstract

Aims

Published research was reviewed to investigate:

1) whether children with mental health symptoms showed different levels of emotion understanding in comparison to healthy peers;
2) if a difference existed, whether it was specific to certain mental health symptoms; and
3) whether differences in emotion understanding increased the risk for later development of mental health symptoms.

Methods

Literature searches were used to identify studies in peer-reviewed journals that measured both emotion understanding and mental health symptoms in neurotypical young children.

Results

38 papers were reviewed: 16 reported a link between emotion understanding and mental health, 14 reported no link, and 8 did not report an analysis of this relationship. The majority of studies reporting a link were population studies of younger school children. Teacher-report of mental health symptoms more commonly revealed a link with emotion understanding than parent, clinician or self-report. There was less evidence of a relationship with emotion understanding for internalising, compared to externalising, symptoms; however the inclusion of depression in internalising disorders may account for this as no evidence of a specific link with depression was found. There was limited evidence that early emotion understanding difficulties predict later mental health symptoms. Other factors including language skills and cognitive ability appear related to emotion understanding, but this may be partly as a result of the verbal and cognitive demands of emotion understanding tasks.

Conclusions

Further longitudinal research is required, using methods capable of producing emotion understanding scores for specific emotions and components of emotion understanding, in combination with disorder-specific mental health measures.

Introduction

In children, the interaction of different developmental domains impacts on social behaviour, psychological functioning and well-being. The impact of some processes, such as executive functioning, have been studied in detail – however others, including the development of emotion understanding, have received less attention. Emotion understanding affects and is affected by social behaviour (Peterson & Tremblay, 1999), as the ability to understand what another person is feeling is central to a child's social skills and relationships. This review explored the relationship between emotion understanding and mental health symptoms in young children.

Emotion Understanding

Emotion understanding is a broad term and can be used to include the recognition of emotion in facial expressions, behavioural cues or tone or voice, in addition to the ability to describe and regulate one's own emotions. Emotion understanding also incorporates the ability to reason on the basis of others' beliefs or desires about the cause of their emotions. This allows predictions to be made about the impact others' emotions are likely to have on their behaviour. An important aspect of emotion understanding is the ability to understand another person's emotions given a particular context. Children's ability to predict how someone will feel in a certain context can increase positive social interactions and prosocial behaviour (Denham, 1986).

Development of emotion understanding. Longitudinal studies demonstrate that children's emotion understanding improves with age, but also that there are individual differences in the level of emotion understanding which remain stable over time (Pons & Harris, 2005). A significant portion of the variance in emotion understanding has been shown to be explained by age and language ability (72%; Pons, Lawson, Harris, & de Rosnay, 2003). However, even in children of the same age, levels of emotion understanding can be markedly different.

Pons, Harris and de Rosnay (2004) have categorised elements of emotion understanding into three developmental phases: the external, mental and reflective phases. These are conceptualised as each containing distinct emotion understanding skills. The first phase is found at approximately 5 years of age and includes the ability to recognise emotional expressions and understand emotions by reference to external causes. The second phase occurs around 7 years when the role of beliefs and desires, and the concept of hiding emotions are understood. The third phase is reached from 9 to 11 years and at this point mixed emotions can be understood in addition to the impact of morals and cognitive emotion regulation. Each phase builds on the previous one, in a causal hierarchy of development.

In contrast, a 2-factor structure has since been proposed by Bassett, Denham, Mincic and Graling (2012). The first factor comprises recognition of expressed emotion, the second an understanding of situation-based emotions. When compared to single or 3-factor models, this 2-factor structure was found to better fit the data from 4 year old children – suggesting that these 2 factors of emotion understanding appear to be distinct. A hierarchical causal structure has been suggested, with the first factor a pre-requisite for development of the second.

O'Brien et al. (2011) found that emotion understanding appears to be distinct from theory of mind (ToM). Emotion understanding appears to develop first and predict later ToM ability. The ability to understand emotional states appears to aid and inform the development of understanding another's thinking.

Impact of emotion understanding. Understanding how another person feels, allows better prediction of their behaviour and also supports successful social interactions (Bassett et al., 2012). Emotion understanding has been shown to significantly predict children's social adjustment, where ToM has not (Deneault & Ricard, 2013) suggesting that insight into others' emotions is more important than insight into others' cognitions for social relationships in young children. Understanding others' emotional states and the impact these have on others' behaviour can allow children to engage in imaginary play together, build close relationships, empathise and comfort others (Cutting & Dunn, 2002). Enhanced social skills and the early development of close friendships may act as protective factors, reducing the risk of developing mental health symptoms.

The ability to understand others' emotions allows the development of empathy. Children with high levels of empathy appear more socially sensitive: showing more prosocial and less aggressive behaviour (Findlay, Girardi, & Coplan, 2006). Equally, children with less developed emotion understanding can find others' behaviour confusing. Low emotion understanding was found to be an early warning, predicting longitudinal patterns of anger and aggression in 3 to 5 year olds (Denham et al., 2002). It may be that lack of insight into others' emotional worlds can create frustration and lead to higher levels of externalising symptoms in later life.

However, there may also be a cost to emotion understanding. Cutting and Dunn (2002) found that children with higher levels of emotion understanding, who were able to understand how others felt about them, were more sensitive to criticism and that this affected their self-worth. Differences in emotion understanding at preschool could therefore affect developmental trajectories, potentially with better emotion understanding predicting increased internalising symptoms.

Mental Health and Emotion Understanding

Cognitive biases are commonly described as contributing to mental health symptoms, however there also appear to be biases in emotional processing. Research suggests that depressed individuals differ from healthy controls in their ability to identify facial expressions, especially of subtle positive expressions (Joormann & Gotlib, 2006). Gotlib and Joormann (2010) describe how misreading emotions in facial expressions can result in situations being interpreted differently, impacting on the choice and success of emotion-regulation strategies. In conduct disorder there has also been research into the recognition of emotional expressions. Woodworth and Waschbusch (2008) found different selective impairments in the ability to recognise specific emotions in youths with conduct problems compared to youths with high callous unemotional traits. As recognition of emotion in facial expressions is considered to be the more basic level of emotion understanding and a pre-requisite for affective perspective taking, impairments in basic emotion recognition are likely to suggest severe emotion understanding difficulties.

Although Emotional Intelligence (EI) is a broader category than emotion understanding, EI tools such as the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT; Mayer, Salovey, & Caruso, 2002) include the ability to perceive emotions in others and to understand emotions. Brackett, Rivers and Salovey (2011) report negative correlations between MSCEIT scores and mental health conditions including depression, social anxiety and schizophrenia and suggest that emotional intelligence may be protective against mental health conditions in adolescents. This is supported by the findings of a systematic review (Resurrección, Salguero, & Ruiz-Aranda, 2014) which showed EI was negatively associated with internalising problems. It also found that adolescents with high EI reported lower levels of stress, fewer risk behaviours, more positive and fewer maladaptive coping strategies. This may in part be due to emotion regulation skills, which are included in the definition of EI, however it appears that emotion understanding is potentially a protective factor against the development of mental health symptoms.

Previous Review

In 2010, Trentacosta and Fine published a meta-analysis investigating emotion understanding, social competence, internalising and externalising problems in children and adolescents. A small to medium effect size (r = -.17) was found to describe the relationship between both emotion understanding and internalising problems, and between emotion understanding and externalising problems, suggesting that emotion understanding is a consistent correlate of mental health symptoms.

Heterogeneity was not found in effect sizes for internalising problems and so characteristics of the samples and methods were not examined as possible moderators. It was suggested that emotion understanding may contribute differently to specific internalising disorders such as anxiety and depression.

Moderators were examined for externalising problems and significant moderators included:

- the sample (small mean effect sizes for population samples, but medium mean effect sizes for clinical samples);
- age (small mean effect sizes for early and middle childhood, but medium to large mean effect sizes for preadolescent/adolescent samples); and
- source of externalising symptoms rating (small mean effect sizes for parent-, teacher- or combination reports, but medium to large mean effect sizes for placement status, observer or diagnosis).

These findings suggest that clinically diagnosed or referred adolescents with externalising difficulties show the largest deficits in emotion understanding. It may be that higher rates of clinical diagnosis or referral are found in adolescents and that as age norms for emotion understanding are substantially higher for this group, any deficits are more easily identified. This may particularly be the case given that Trentacosta and Fine's meta-analysis (2010) included studies looking solely at emotion recognition – a skill which is commonly developed in early childhood.

Current Review

This review updated Trentacosta and Fine's 2010 study, but with a narrower focus: the relationship between affective perspective taking and mental health symptoms in children under 13 years old. In this review, where possible, specific internalising symptoms were kept separate to investigate whether distinct emotion understanding profiles were linked to different internalising symptoms. Narrower age groupings were used, as recommended by Trentacosta and Fine (2010), and the focus was solely on children rather than also encompassing teenagers (requiring a mean age under 13 rather than 18 years) to look in more detail at the age range found to have small effect sizes in the meta-analysis. A more specific emotion understanding definition was used: affective perspective taking rather than also including tests solely of emotion recognition, as these elements of emotion understanding have been shown to be distinct (Bassett et al., 2012). Affective perspective taking was chosen as it is the more advanced skill and emotion recognition is encompassed as a pre-requisite for its development. New research was included as the literature search for Trentacosta and Fine's 2010 meta-analysis was performed in 2004 (details are provided in the methods section).

Aims

This review aimed to identify all studies to date which measured both emotion understanding and mental health symptoms in children under 13, to develop a better understanding of any relationship between these factors. Specifically, this review aimed to investigate:

1) whether children with mental health symptoms showed different levels of emotion understanding to their healthy peers;
2) if there is a difference, whether this is consistent across different types of mental health symptoms; and
3) whether differences in emotion understanding increased the risk of later developing mental health symptoms.

Methods

Search Strategy

A literature search was performed on 30th December 2014 using PsychINFO and PubMed databases to identify studies measuring both emotion understanding and mental health symptoms in young children. Citations of accepted papers were searched using Web of Science and reference lists were manually searched. In addition, studies included in Trentacosta and Fine's 2010 meta-analysis were manually checked.

Search Terms

Table 1 details the search terms used: results from the emotion understanding, mental health and child searches were combined using the AND operator. Subject heading searches were used in combination with text word searches of title, abstract, keywords and additional headings used by the databases.

Table 1

Search Terms for Literature Search

Concept	**Type of search**	**PsychINFO**	**PubMed**
Emotion understanding	Subject heading	Emotional Development Emotional Intelligence Mentalization	Emotional Intelligence
	Text word	“emotion* understand*” “affect* understand*” “emotion* comprehen*” “affect comprehen*” “understand* feeling*” “mentalis*” “mentaliz*”	“emotion* understand*” “affect* understand*” “emotion* comprehen*” “affect comprehen*” “understand* feeling*” “mentalis*” “mentaliz*”
Mental health	Subject heading	Adjustment Disorders Affective Disorders Anxiety Disorders Dissociative Disorders Eating Disorders Child Psychopathology Childhood Psychosis	Adjustment Disorders Anxiety Disorders Dissociative Disorders Eating Disorders Mental Disorders (diagnosed in childhood) Mood Disorders Childhood Schizophrenia Child Psychiatry
	Text word	“mental health” “mental disorder*” “mental ill*” “anxiety” “depression” “phobia” “panic” “obsessive compulsive” “psychiatric” “psychosis” “PTSD” “OCD” “GAD” “eating disorder*” “bulimia” “anorexia” “post-trauma*” “post trauma*”	“mental health” “mental disorder*” “mental ill*” “anxiety” “depression” “phobia” “panic” “obsessive compulsive” “psychiatric” “psychosis” “PTSD” “OCD” “GAD” “eating disorder*” “bulimia” “anorexia” “post-trauma*” “post trauma*”
Child	Subject heading		Child Preschool Child
	Text word	“child*” “boy*” “girl*” “young*” “paediatric*” “pediatric*” “infant*”	“child*” “boy*” “girl*” “young*” “paediatric*” “pediatric*” “infant*”

Note. *Subject heading:* thesaurus searching with all headings exploded to include all sub-categories. *Text word:* in PsychINFO these searched: title, abstract, heading word, table of contents, key concepts, original title, tests and measures. In PubMed these searched: title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word and unique identifier. *PubMed search:* included Ovid MEDLINE (R) In-Process & Other non-indexed citations and Ovid MEDLINE (R) 1946 to Present.

Inclusion and Exclusion Criteria

Inclusion criteria included being written in English and published in a peer-reviewed journal before the end of 2014. The study had to include details of the participants and measures used, and include a neurotypical population with a mean age of less than 13 years. Measures of both emotion understanding and mental health symptoms were required.

Emotion understanding was defined for this review as an ability to understand someone else's emotional state given information about their situation – affective perspective taking. Therefore studies evaluating solely recognition of emotions from facial expressions or tone of voice, or studies evaluating only the child's ability to describe their own emotions were excluded. Additionally, to reduce bias, the child's emotion understanding had to be assessed directly, so studies with only parental report of their child's emotion understanding were excluded.

Measures of mental health symptoms were included whether they were for one specific type of symptom, or were generic mental health measures. Diagnoses of a mental health difficulty by a trained professional and mental health measures completed by the child, parent or teacher were all accepted. As this review focused only on the neurotypical population, studies were excluded if they were conducted exclusively with children with learning difficulties, brain injuries, physical health conditions, attention deficit hyperactivity disorder (ADHD) or autistic spectrum disorder (ASD). Studies were also excluded if they used only the emotion control subscale of mental health screening tools or investigated only a child's ability to emotionally regulate.

Search Results

3889 papers were identified using the PsychINFO and PubMed searches. After duplicated papers were removed, titles and abstracts were screened to identify papers in the area of this review. 107 papers were identified, and the full text was used to establish if they met the criteria outlined above. 14 were accepted, and references and citation searches of these papers identified additional records which, together with papers used in Trentacosta and Fine's meta-analysis (2010) and 3 papers identified through preliminary reading, were also screened. Four additional papers were included from the meta-analysis (2 had been included in the initial search), 7 from the references, 10 from citations and 1 from the preliminary reading papers. Reference checking of these additional papers identified further papers to screen, of which two which were accepted. In total 38 articles meeting the criteria for the review were identified. Figure 1 illustrates the number of records at each stage of the review process.

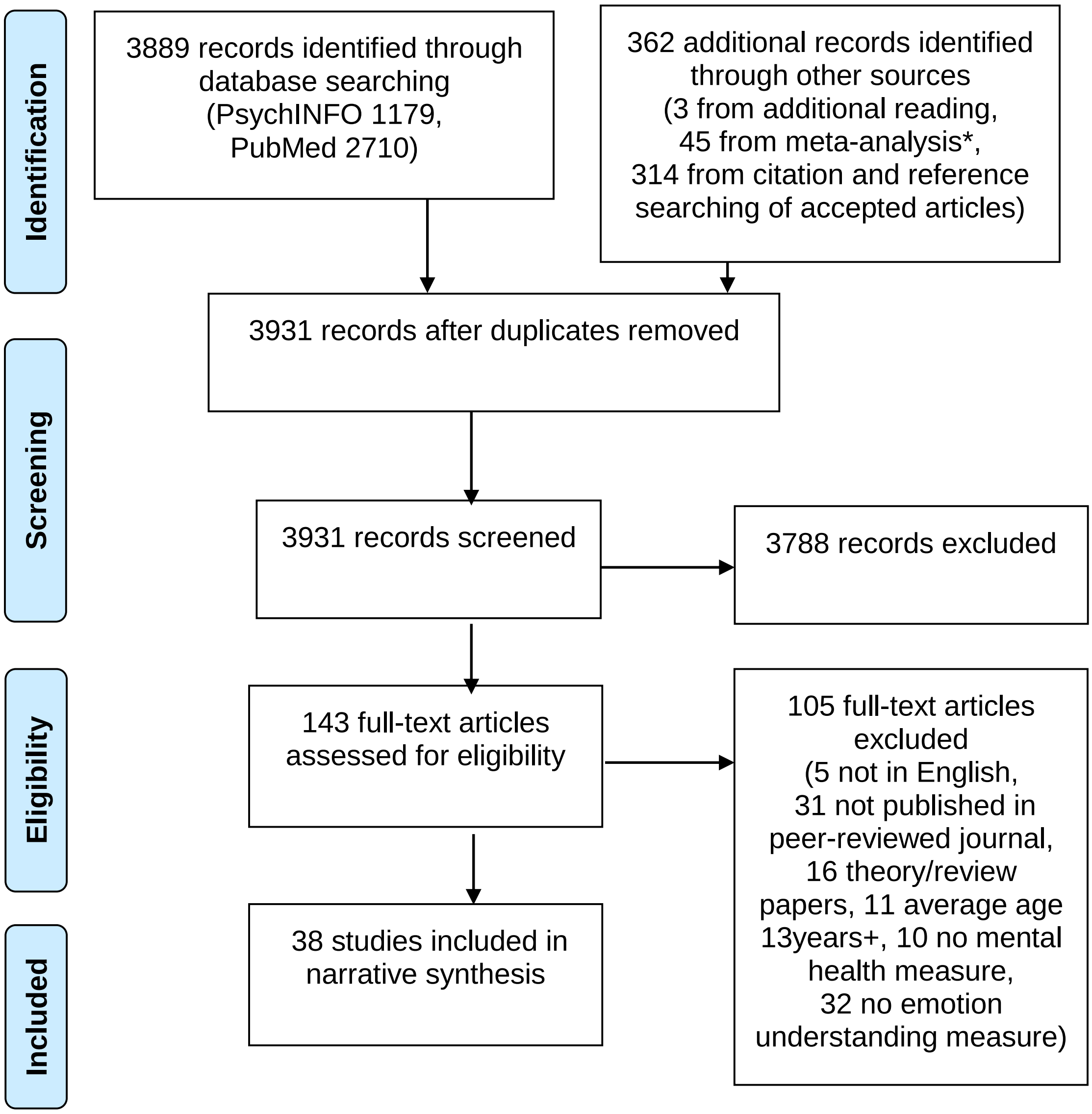

Figure 1. PRISMA flow diagram (Moher, Liberati, Tetzlaff, Altman, & the PRISMA Group, 2009) depicting the flow of information through the different phases of review.

*Meta-analysis (Trentacosta & Fine, 2010).

Comparison with Trentacosta and Fine's Meta-analysis (2010)

Trentacosta and Fine's 2010 meta-analysis identified 89 articles. Of these 44 looked at social competence rather than mental health symptoms and so were not included in the current review. Of the remaining 45 which looked at internalising or externalising disorders: 10 were not published in peer-reviewed journals and 4 did not include mental health symptoms according to the criteria above (they used only classroom observation, or looked solely at behaviour regulation or social problems) and a further 6 measured only emotional expressiveness, regulation or emotionality – again outside of the mental health symptom definition used here. A further 19 studies used only measures of emotion recognition – outside of the definition of emotion understanding used for this review. The remaining six articles were included in this review.

32 articles included in this review were not included in Trentacosta and Fine's 2010 meta-analysis. Of these, 20 were published in or after 2004 when the PsychINFO search for the meta-analysis was performed. The remaining 12 papers may not have been included as they were identified using a subject heading search or using PubMED both of which were not used in the meta-analysis. Four studies might have been excluded from the meta-analysis as the sample was primarily composed of children with neurodevelopmental disorders (which was an exclusion criteria for the meta-analysis) but have been included here as they also contain a control group of neurotypical children with psychiatric symptoms. Both mental health and emotion understanding are broad categories with many different possible terms – the search terms used for this review differ from those used in the meta-analysis. For example, this review searched for emotion comprehension and affective disorders which were not included in the search strategy for the meta-analysis, and may explain why some additional articles published prior to 2004 have been included here.

Overall, 84% of articles included in this review were not included in Trentacosta and Fine's 2010 meta-analysis and over half were not published when the literature search for the meta-analysis was performed. The definition used for emotion understanding in this review is narrower, excluding studies looking solely at emotion recognition which made up 42% of the internalising and externalising studies used in the meta-analysis. Together, these differences support the need for this further review of literature in this area.

Results

First, study and sample characteristics are discussed, emotion understanding tasks are then critically reviewed and finally mental health symptom reports are explored. The literature is then evaluated in terms of the three questions posed by this review, and potential moderating and mediating factors are discussed.

Study and Sample Characteristics

38 studies were included in the narrative synthesis. Of these 23 were population-based studies and 15 were clinical studies – sample characteristics can be found in Tables 2 and 3 respectively. Studies were defined as clinical if a mental health (rather than physical disability) group was used. Overall, 31 independent samples were used by the studies (20 population samples and 11 clinical samples).

Although the majority of studies were cross-sectional, there were 12 longitudinal studies, ranging from 3 to 48 months in duration. Sample sizes ranged from 16 to 332 participants and most had approximately equal proportions of male and female participants: 76% of studies (including all population studies) reported between 40% and 60% of subjects to be male. The overall range was 42-100% male, with male-bias mostly occurring in samples of autism, conduct or behavioural problems, which predominantly occur in boys.

Mean age ranged from 2.4 to 12.3 years (taking the psychiatric group mean age where groups differed). Studies were then grouped by mean age into four categories: under 4, 4 to 4.9, 5 to 9.9 and 10 to 12.9 (see Tables 4, 5, 6 and 7 respectively). 53% of the studies were carried out with children with a mean age between 4 and 4.9 years which is why a separate group was created for this age range. The overall age range included children over 13 in five clinical studies (three with different samples), with a maximum age of 19 years.

Where stated, ethnic and social background indicated that studies predominantly took place in urban (17 studies) rather than rural areas (2 studies). Of the population studies, 10 specified that samples contained low income families, whilst 3 specifically looked at middle-class families. Seven studies reported samples with over 90% of a single ethnicity (three Caucasian, three African-American and one Asian-American).

As inclusion criteria required that studies were published in English, a bias in location was introduced. Twenty-one studies took place in the USA, seven in the UK, three in Australia, one in Canada and the remaining six in continental Europe. Population samples were recruited predominantly from preschools and schools, whilst clinical samples were recruited from mental health facilities and programmes, or identified by the use of screening measures in school populations.

Table 2

Population Studies Investigating the Relationship between Emotion Understanding and Mental Health Symptoms: Sample Details (23 studies)

Ref	Paper	Study type (duration if longitudinal)	Number of participants (male)	Mean age in years (*SD*, range)	Ethnic & social background	Sample source (location of study)	Groups
2	Williams, Daley, Burnside, & Hammond-Rowley, 2010	Longitudinal Population Study (Year 6 & post-transition in Year 7)	274 (134)	10 or 11 years at time 1 (exact details not stated)	Rural area	Schools pre & post transition (North Wales, UK)	N/A
4	Kidwell, Young, Hinkle, Ratliff, Marcum, & Martin, 2010	Cross-sectional Population Study	54 (31)	4.5 (0.4, range not stated)	Rural area, low income families, over 90% Caucasian	Preschool programmes for low income families (Appalachia, USA)	N/A
5	Cunningham, Kliewer, & Garner, 2009	Longitudinal Population Study (6months)	69 (34)	11.29 (1.26, 9-13)	Midsized city, 100% African American	Moderate to high violent neighbourhoods (South-east USA)	N/A
7	Piek, Bradbury, Elsley, & Tate, 2008	Cross-sectional Population Study	41 (22)	4.3 (0.33, 3.75-5.3)	Not stated	Regional primary school (Western Australia)	N/A
8	Cummins, Piek, & Dyck, 2005	Cross-sectional Population Study	MD: 39 (22), Control: 39 (22)	MD: 9.9 (2, 6.9-12.9), Control: 10 (1.9, 6.9-12.9) Overall 9.6 (1.7, 6.7-12.9)	Metropolitan area	Schools (Perth, Western Australia)	2: MD (Motor Difficulty) & Control

10	Miller, Fine, Gouley, Seifer, Dickstein, & Shields, 2006	Cross-sectional Population Study	60 (25)	4.34 (0.53, 3.4-5.2)	Small city, low income families, 45% Caucasian, 17% African-American, 10% Latino, 27% Mixed race, 1% Not stated	Head Start programme in schools (North-east USA)	N/A
11	Huang, Cheng, Calzada, & Brotman, 2012	Cross-sectional Population Study	101 (50)	4.16 (0.45, 3-5)	Large city, 56% defined as poor, 100% Asian-American	Pre-kindergarten programs (USA)	N/A
12	Raimundo, Marques-Pinto, & Lima, 2013	Longitudinal Population Study (20months)	318 (175)	9.31 (0.56, range not stated)	City, predominantly middle class	State primary schools (Lisbon, Portugal)	2: Intervention & Control
14	Ensor & Hughes, 2005	Cross-sectional Population Study	36 (17)	2.4 (0.3, 1.7-3)	Small city, predominantly middle class, 100% Caucasian	Mother-toddler groups (Cambridge, UK)	N/A
17	Fine, Izard, Mostow, Trentacosta, & Ackerman, 2003	Longitudinal Population Study (approx. 48months)	108 (54)	Not stated (7 at time 1 when emotion understanding task completed, 11 at time 2)	70% defined as below the poverty threshold. 72% African-American, 20.4% European-American, 6.1% Latino, 1% Other	Head Start Centres (Northern Delaware, USA)	N/A
19	Shields, Dickstein, Seifer, Giusti, Magee, & Spritz, 2001	Longitudinal Population Study (approx. 7months)	49 (22)	4.5 (0.5, 3.4-5.25)	Predominantly defined as impoverished, 70% Caucasian, 6% African-American, 14% Latino, 10% Mixed	Head Start Preschool for low income children (New England, USA)	N/A
21	Dodge, Laird, Lochman, Zelli, & The Conduct Problems Prevention Research Group, 2002	Longitudinal Population Study (approx. 36months)	332 (166)	Not stated (not stated, approx. 6 at time of emotion understanding task)	51% Caucasian, 45% African-American, 4% Other	Schools defined as high risk (USA)	N/A

22	Garner & Lemerise, 2007	Cross-sectional Population Study	94 (48)	4.6 (0.7, 3.4-6)	Large city, low income families: 92% African-American, 5% Caucasian, 3% Latino. Higher income families: 79% African-American, 15% Caucasian, 4% Latino, 2% Asian-American	Preschool programmes (South-west USA)	2: Head Start Preschool (low income) & University Preschool (higher income)
24	Smith, 2001	Longitudinal Population Study (9months)	36 (16)	4.7 (0.5, range not stated)	Low to middle class, 100% African-American	Child-care centres and schools (USA)	N/A
26	Laible, 2004	Cross-sectional Population Study	51 (23)	4.1 (0.8, 3-5)	City, 77% Caucasian, 23% African-American	Day-care centres and preschools (Southern USA)	N/A
27	Alonso-Alberca, Vergara, Fernandez-Berrocal, Johnson, & Izard, 2012	Cross-sectional Population Study	110 (56)	4.4 (0.9, 3-6)	Urban middle class area, 90.9% Caucasian, 3.64% African-European, 2.73% Romani, 2.73% Mixed	Preschools (Spain)	N/A
28	Bassett, Denham, Mincic, & Graling, 2012 [a]	Longitudinal Population Study (3months)	324 (159)	4.1 (0.6, range not stated)	Low income: 19.7% Caucasian, 61.9% African-American. Higher income: 63.3% Caucasian, 18.6% African-American, 4.5% Asian	Head Start and private child-care centres (Northern Virginia, USA)	2: Head Start (low income) & Private child-care (higher income)
30	Denham, Bassett, Mincic, Kalb, Way, Wyatt, & Segal, 2012[1] [a]	Longitudinal Population Study (3months)	275 (135)	Wave 1: 4.6 (0.3, range not stated) Wave 2: 4.4 (0.3, range not stated)	Low income: 20% Caucasian, 61% African-American. Higher income: 68% Caucasian, 16% African-American	Head Start and private child-care centres (Northern Virginia, USA)	2: Head Start (low income) & Private child-care (higher income) (waves of recruitment)

31	Denham, Bassett, Way, Mincic, Zinsser, & Graling, 2012[2 a]	Longitudinal Population Study (3months between time 1 and time 2 then time 3 the next school year)	322 (approx. 161)	4.1 (0.6, range not stated)	Low income & higher income families. 43.5% Caucasian, 38.5% African-American, 12.1% Hispanic	Head Start and private child-care centres (Northern Virginia, USA)	2: Head Start (low income) & Private child-care (higher income)
33	Dunn, Cutting, & Demetriou, 2000 [b]	Cross-sectional Population Study	128 (65)	4.2 (*SD* not stated, 3.5-4.8)	City, equally middle and working class, 68% Caucasian, 26% Black or mixed race, 6% Other	Nursery schools (London, UK)	N/A
36	Morgan, Izard, & King, 2009	Cross-sectional Population Study	59 (31)	4.7 (1, 3.1-6.2)	69% Caucasian, 16% African-American, 12% Asian-American, 2% Other	University day-care centres (mid-Atlantic region, USA)	N/A
37	Leerkes, Paradise, O'Brien, Calkins, & Lange, 2008	Cross-sectional Population Study	141 (72)	3.5 (*SD* not stated, 3.3-3.7)	Small city, 66% Caucasian, 25% African-American, 10% Other	Preschools and child-care centres (South-east USA)	N/A
38	Dunn & Cutting, 1999 [b]	Cross-sectional Population Study	128 (65)	4.16 (*SD* not stated, 3.49-4.8)	City, equally middle and working class (including considerable urban deprivation), 68% Caucasian, 26% Black or Mixed, 6% Other	Nursery schools (London, UK)	N/A

a – these three studies are all part of a larger investigation. b – these two studies use the report the same sample.

Table 3

Clinical Studies Investigating the Relationship between Emotion Understanding and Mental Health Symptoms: Sample Details (15 studies)

Ref	**Paper**	**Study type (duration if longitudinal)**	**Number of participants (male)**	**Mean age in years (*SD*, Range)**	**Ethnic & social background**	**Sample source (location of study)**	**Groups**
1	Buitelaar & van der Wees, 1997 [c]	Cross-sectional Clinical Study	AUT: 20 (18), PPDNOS: 20 (17), PsCON: 20 (12), NOR: 20 (7)	AUT: 12.5 (3.2, 9-18.5), PPDNOS: 12.4 (3.1, 8-18.6), PsCON: 12.3 (3.2, 8-18.2), NOR: 10.5 (1.9, 8-12)	Not stated	Utrecht Department of Child Psychiatry, NOR from primary school (Holland)	4: AUT (autistic spectrum disorder), PPDNOS (pervasive developmental disorder not otherwise specified), PsCON (psychiatric control) & NOR (control)
3	Dyck, Ferguson, & Shochet, 2001	Cross-sectional Clinical Study	NPD: 36 (27), AutD: 20 (17), MR: 34 (18), ADHD: 35 (31), AnxD: 14 (7), AspD: 28 (24)	12.09 (2.2, 9-16)	Not stated	Hospitals, clinics, special education units & schools (Brisbane, Australia)	6: NPD (no psychiatric disorder), AutD (severe ASD), MR (relatively severe disability), ADHD, AnxD (anxiety disorder without ASD) & AspD (less severe ASD).
6	Martin, Williamson, Kurtz-Nelson, & Boekamp, 2015	Cross-sectional Clinical Study	79 (54)	4.6 (0.8, 3-5)	6.3% African-American, 59.5% European-American, 7.6% Hispanic-American, 22.6% Other	Admitted to hospital-based day treatment program for young children with severe emotional and behavioural problems (USA)	N/A

9	Fox, Warner, Lerner, Ludwig, Ryan, Colognori, Lucas, & Brotman, 2012	Longitudinal Clinical Study (6months)	16 (9)	4.1 (0.8, 3-5)	City, 62.5% Caucasian, 12.5% Asian, 25% Mixed	Preschools, paediatric practices, local schools and mental health centres (New York, USA)	N/A
13	Ramos-Marcuse & Arsenio, 2001	Cross-sectional Clinical Study	BP: 22 (13), Control: 23 (12)	BP: 4.9, Control: 4.5 (*SD* and range not stated)	Urban community, BP: 50% African-American, 36% Latino, 14% European-American. Control: 48% African-American, 48% Latino, 4% European-American	Child mental health outpatient clinic and preschools (North-east USA)	2: BP (Behavioural Problems) & Control
15	Arsenio & Fleiss, 1996	Cross-sectional Clinical Study	BD: 24 (20) Control: 24 (20)	BD: younger 7.3, older 11.2 Control: younger 7.6, older 10.7 (no *SD* or range given)	Middle to lower-middle class. Approx 66% Caucasian, 33% African-American or Hispanic	Elementary school and mental health facility (USA)	2: BD: mental health facility group with behavioural difficulties (with younger and older subgroups) & Control: school group (with younger and older subgroups)
16	Buitelaar, van der Wees, Swaab-Barneveld, & van der Gaag, 1999[1 c]	Cross-sectional Clinical Study	AUT: 20 (18), PPDNOS: 20 (17), PsCON: 20 (12), NOR: 20 (7)	AUT: 12.5 (3.2, 9-18.5), PPDNOS: 12.4 (3.1, 8-18.6), PsCON: 12.3 (3.2, 8-18.2), NOR: 10.5 (1.9, 8-12)	Not stated	Utrecht Department of Child Psychiatry, NOR from primary school (Holland)	4: AUT (autistic spectrum disorder), PPDNOS (pervasive developmental disorder not otherwise specified, PsCON (psychiatric control) & NOR (control).

18	Hughes, Dunn, & White, 1998 [d]	Cross-sectional Clinical Study	H2M: 40 (24), Control: 40 (24)	H2M: 4.3 (0.4, 3.5-4.5), Control: 4.1 (0.3, 3.5-4.5)	City, H2M: 55% Caucasian, 45% Black or Asian. Control: 70% Caucasian, 30% Black or Asian	State schools and nurseries (London, UK)	2: H2M (hard to manage – above 90th percentile for hyperactivity, 80% also above 90th percentile for conduct problems) & Control.
20	Woodworth & Waschbusch, 2008	Cross-sectional Clinical Study	CP: 32 (27), CPCU: 24 (20), Control: 17 (12)	CP: 9.8 (1.77), CPCU: 9.81 (1.57), Control: 9.83 (1.52). Overall: 9.81 (1.64, 7.04-12.78)	84.3% Caucasian, 4.3% African-Canadian, 11.4% Other	Summer day treatment programme for children with disruptive behaviour problems (Atlantic Canada)	3: CP (conduct problems only), CPCU (conduct problems with callous-unemotional traits) & Control.
23	MacQuiddy, Maise, & Hamilton, 1987	Cross-sectional Clinical Study	24 (24)	BP: 6.9 (0.9, 5.2-7.9), Control: 6.75 (0.8, 5.6-8)	Not stated	Recruited through adverts (USA)	2: BP (behaviour problems) & Control.
25	Termini, Golden, Lyndon, & Sheaffer, 2009	Cross-sectional Clinical Study	RAD: 20, NonRAD: 18, Control: 35. Overall: 73 (36)	10.19 (3.38, 5-19)	41% Caucasian, 35.6% African American, 6.8% Mixed, 6.8% Hispanic, 2.7% Native American, 6.8% Undisclosed	Foster care groups through social services and therapists, control from after-school programme (USA)	3: RAD (foster care and Reactive Attachment Disorder diagnosis), NonRAD (foster care without RAD diagnosis), & Control (non-foster care, no RAD diagnosis).
29	Buitelaar, van der Wees, Swaab-Barneveld, & van der Gaag, 1999[2] [c]	Cross-sectional Clinical Study	AUT: 20 (18), PPDNOS: 20 (17), PsCON: 20 (12)	AUT: 12.5 (3.2, 9-18.5), PPDNOS: 12.4 (3.1, 8-18.6), PsCON: 12.3 (3.2, 8-18.2)	Not stated	Utrecht Department of Child Psychiatry (Holland)	3: AUT (autistic disorder), PPDNOS (pervasive developmental disorder not otherwise specified), & PsCON (psychiatric control).

32	Downs & Smith, 2004	Cross-sectional Clinical Study	ASD: 10 (10), ADHD+ODD: 16 (16), Control: 10 (10)	ASD: 7.8 (1.1, 5.7-9.75), ADHD+ODD: 8.25 (1, 5.7-9.7), Control: 7.6 (1.2, 6.3-9.2)	Not stated	Young ASD projects, outpatient treatment programmes and control from public school (USA)	3: ASD (high functioning following behavioural treatment), ADHD + Oppositional Defiant Disorder (ODD) & Control.
34	Hughes & Dunn, 2000 [d]	Longitudinal Clinical Study (24months)	H2M: 40 (24), Control: 40 (24)	H2M: 4.3 (0.4, 3.5-4.5), Control: 4.2 (0.3, 3.5-4.5) at time 1. Emotion understanding task at time 2: H2M: 6.2 (0.3), Control: 6.1 (0.3). *grouped as age at time 2	City, H2M: 55% Caucasian, 45% Black or Asian. Control: 70% Caucasian, 30% Black or Asian	State schools and nurseries (London, UK)	2: H2M (hard to manage – above 90th percentile for hyperactivity, 80% also above 90th percentile for conduct problems) & Control.
35	Hughes, White, Sharpen, & Dunn, 2000 [d]	Cross-sectional Clinical Study	H2M: 40 (24), Control: 40 (24)	H2M: 4.3 (0.4, 3.5-4.5), Control: 4.2 (0.3, 3.5-4.5)	City, H2M: 55% Caucasian, 45% Black or Asian. Control: 70% Caucasian, 30% Black or Asian	State schools and nurseries (London, UK)	2: H2M (hard to manage – above 90th percentile for hyperactivity, 80% also above 90th percentile for conduct problems) & Control.

c – these three studies report the same sample. d – these three studies report the same sample.

Review of Emotion Understanding Tasks

Many different emotion understanding tasks were used, including 11 named tests and several tasks developed for an individual study. Overall, the tasks have been categorised as falling into one of five groups:

- Affective Knowledge Task (AKT; Denham, 1986) used in 13 studies;
- Verbal vignettes used in 13 studies – including the Preschool Emotion Interview (PEI; Garner, Jones, & Miner, 1994), Emotion Matching Task (EMT; Izard, Haskins, Schultz, Trentacosta, & King, 2003) and Emotion Recognition Questionnaire (ERQ; Ribordy, Camras, Stefani, & Spaccarelli, 1988);
- Drawn vignettes used in seven studies;
- Emotion Recognition Scales (ERS; Dyck, Ferguson, & Shochet, 2001) used in three studies; and
- Other tasks used in six studies.

Three studies used multiple measures of emotion understanding and no one task was used across all age groups.

AKT (Denham, 1986). The AKT was only used with children under 5 years old, was the only measure used for the under 4 studies and the measure most commonly used with 4 year olds. The AKT involves a puppet with several detachable faces showing different emotions. The measure has two parts: affective labelling and affective perspective taking. As outlined in the inclusion criteria, only studies which included the affective perspective taking task were included.

In the affective perspective taking task, a puppet acts out a story with the puppeteer using appropriate emotional expressions and tone of voice and the child is asked to choose which emotion face is right for the puppet. Generally (but not in all studies), both stereotypical emotional responses (the response a parent believes their child would have) and equivocal emotional responses (the opposite response to that predicted by the parent) are tested. This tests that children are not simply answering with the emotion they would feel and are truly required to consider someone else's emotional response.

However, there are difficulties with using this as a measure of affective perspective taking. The child could correctly answer each question by recognising the emotional expression of the puppeteer and choosing the matching facial expression for the puppet, without appreciating the link between the story and the emotion. Also, the child could answer the equivocal stories incorrectly if they are paying attention to the story, but not to the emotional cues given by the puppeteer. Ideally, the stories would be presented without emotional cues (as in Miller et al., 2006), and use only the stereotypical stories (as in Ensor & Hughes, 2005). However, scores for stereotypical and equivocal responses have been found to significantly correlate ($r(137) = .55$; $p < .001$) (Leerkes, Paradise, O'Brien, Calkins, & Lange, 2008) and show a good to excellent level of internal consistency ($\alpha = 0.93$; Denham, 1986; $\alpha = 0.86$; Denham, McKinley, Couchoud, & Holt, 1990).

Results from the affective perspective taking task were commonly grouped together with those of the affective labelling subtest which tests only emotion recognition. However, research suggests that although it is theorised that these are distinct emotion understanding abilities (with recognition a prerequisite for affective perspective taking) there is an excellent level of internal consistency across these measures ($\alpha = 0.95$; Denham, 1986). This may be explained by the use of emotion cues in the affective perspective taking task: potentially both of these subtests assess emotion recognition rather than affective perspective taking.

Verbal vignettes. Procedures that described the use of verbal vignettes were the type of measure most commonly used with 6 to 9.9 year olds. As this is a description of the method of administration, rather than a specific task, they were difficult to compare as the vignettes used and the complexity of the stories varied between studies. Some studies offered a choice of visual emotional expressions which could be pointed at, while others required a verbal response. In contrast to the

AKT, these tasks tended to be more pure measures of affective perspective taking, without instructions for researchers to provide verbal and tone of voice cues. The correct answer was also constant – rather than varying depending on a child's own likely response.

It is interesting that verbal vignettes were used more commonly with the younger age groups (4 and 6-9.9 years), whereas drawn vignettes, requiring less information to be held in working memory, were more commonly used for the older group (10-12.9 years). Verbal ability has been shown to explain some of the variance in emotion understanding, however this may in part be due to the method of vignette presentation – requiring a verbal story to be processed and understood without support from visual cues.

Drawn vignettes. Procedures that used drawings (without facial expressions) to tell a vignette were the type of measure most commonly used for the oldest group (10-12.9 years) and the measure used in most clinical studies. While addressing to some extent the reliance on working memory and verbal ability by providing stories in a visual format, these tasks required skills to attend to and comprehend visual information. This is a description of the method of administration rather than a specific standardised task and therefore variance was found in the complexity of the stories and the quality and type of drawings used. The extent to which body language in the drawings can be used an as indication of emotion may also vary between these tasks. However, like the verbal vignettes, these tend to be more pure measures of affective perspective taking: with no instructions that the researcher should use verbal or tone of voice cues and a standard correct answer for every child.

ERS (Dyck et al., 2001). The ERS was used once in each of the three oldest age groups. It consists of five subtests:

- Fluid Emotions Test (FET) – recognition of facial expressions of emotions;

- Vocal Cues Test (VCT) – recognition of emotions in tone of voice;
- Emotion Vocabulary Test (EVT) – definition of emotion words;
- Comprehension Test (CT) – contextual understanding of emotion; and
- Unexpected Outcomes Test (UOT) – reasoning for apparently unexpected emotions.

Ideally, the CT, which has good internal consistency (α = 0.85; Dyck et al., 2001), would be used for a pure affective perspective taking score. However, the different subtests are often combined to produce a single emotion understanding score, consisting of a mix of recognition and contextual understanding. The inclusion of the EVT is likely to exaggerate a link with verbal ability, and the UOT uses reasoning abilities requiring a certain level of intelligence: Dyck (2012) states that the UOT is not recommended for use with individuals with intellectual disabilities due to the reasoning skills required. The EVT, UOT and CT are most reliable with typically developing participants or those with autism, and least reliable if participants have ADHD, learning or language difficulties (Dyck, 2012). However, the FET and VCT are least reliable with typically developing participants and show high reliability in those with language difficulties, suggesting that a summed score of the subtests may not be useful for all populations.

Dyck et al. (2001) report that the subtests are all moderately to strongly related to ToM tasks, verbal and performance intelligence tests. Weak correlations across the ERS subtests are reported, with low shared variance suggesting that different constructs are measured by the different subtests (Dyck, 2012). However, analyses support a single latent variable, showing two distinct components (emotion understanding and emotion recognition) from school age (Dyck, 2012). Therefore, combinations of the three understanding subtests (EVT, CT and UOT) may be more useful as a measure of affective perspective taking ability, without recognition elements.

Review of Mental Health Symptom Reports

The mental health symptoms measured were grouped into five categories:

- Internalising and externalising disorders unspecified (10 studies, mostly in the age 4 group);
- Externalising disorders/conduct problems/behavioural problems (14 studies, mostly in the 6 to 9.9 age group – including the majority of the clinical studies);
- Anxiety (10 studies);
- Depression (seven studies, mostly in the oldest age group); and
- Other symptoms (eight studies measured other mental health symptoms only).

The mental health measures were grouped into five categories:

- Diagnosis (eight studies);
- Child Behavior Checklist Parent Form (CBCL; Achenbach, 1991) (eight studies);
- Teacher Report Form of the CBCL (TRF; Achenbach, 1997; Achenbach & Edelbrock, 1986) (nine studies);
- Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997) (six studies); and
- Other measures (nine studies used only one of these ‘other’ measures).

Many different mental health symptom measures were used. An example of a high quality mental health symptom report was the very detailed diagnostic assessment involving parent and child interviews, observations, developmental histories, school records and neuropsychological tests which resulted in diagnosis by two psychiatrists with a high level of inter-rater reliability (Buitelaar & van der Wees, 1997; Buitelaar, van der Wees, Swaab-Barneveld, & van der Gaag, 1999[1]; Buitelaar, van der Wees, Swaab-Barneveld, & van der Gaag, 1999[2]).

However, these assessments created a small psychiatric group (n=20) including diverse diagnoses: ADHD, conduct disorder and depression. These different conditions could have different relationships with emotion understanding reducing the likelihood that an overall relationship would be found for the psychiatric group. In fact Buitelaar et al. (1999[1]) were able to identify that a diagnosis of ADHD significantly affected emotion understanding and that when the remainder of the psychiatric group were compared to the control group no effect on emotion understanding was found, suggesting different mental health diagnoses may have different relationships with emotion understanding.

Mental health symptoms were reported by different sources. Research has shown that mental health reports from different types of informant have small correlations (r =.28), even smaller between self- and other-reports (r =.22), demonstrating the importance of collecting data from multiple informants where possible (Achenbach, McConaughy, & Howell, 1987). Only one study used reports from more than two informants: Kidwell et al. (2010) used parent-, teacher- and self-report in their study of 4.5 year olds. Research suggests that with age-appropriate instruments, children from 5 years old can provide reliable and valid self-report regarding their health (Varni, Limbers, & Burwinkle, 2007), but the use of multiple-informant report is recommended, with studies finding that young people's self-report minimises mental health symptoms, whilst parents and teachers each notice different dysfunctional behaviours (Salbach-Andrae, Lenz, & Lehmkuhl, 2009).

Kidwell et al. (2010) found that different informant-reports were significantly correlated, and scored internalising and externalising symptoms separately: externalising disorders have been found to be particularly poorly predicted by self-report, with teacher-report specifically aiding identification of these symptoms, whilst parent-report specifically aids identification of internalising symptoms (Goodman, Ford, Simmons, Gatward, & Meltzer, 2003). Self-report was not significantly correlated with emotion understanding (the difficulty of accurate self-report from children under 5 years old may have contributed to this), but parent- and teacher-report of both internalising and externalising symptoms were significantly correlated to emotion understanding (Kidwell et al., 2010). Average scores for internalising and externalising subscales were below the clinical threshold in this study, but the range extended above the clinical cut-off. This suggests a relationship between emotion understanding ability and mental health symptoms, both above and below the clinical threshold.

Teachers were the most common informant: used in 22 studies and frequently combined with parent-report for younger children. The Teacher Report Form (TRF; Achenbach, 1997; Achenbach & Edelbrock, 1986) of the Child Behavior Checklist (CBCL; Achenbach, 1991) was the most common measure: used in nine studies, with the parent version (CBCL) used in eight. These measures show moderate agreement for externalising disorders, but low agreement for internalising disorders and total problem scores (Salbach-Andrae et al., 2009). The CBCL/1½-5 (Achenbach & Rescorla, 2000) has been shown to be better at predicting externalising than internalising disorders (de la Osa, Granero, & Ezpeleta, 2013). Studies tend to keep internalising and externalising scores from these measures separate and it may be that externalising results should be given more weight.

However, one study which used the TRF combined teacher-report for children aged 7 years, with self-report when the children were 11 years old (Fine, Izard, Mostow, Trentacosta, & Ackerman, 2003). This study reported that emotion understanding was significantly related to concurrent teacher-rated internalising (but not externalising) symptoms, and that emotion understanding at age 7 significantly predicted, and accounted for 5% of the variance in, self-reported internalising symptoms 4 years later. Although this might appear to suggest that the TRF internalising score should be given more weight, after partialing out the effect of externalising symptoms, teacher's internalising scores were not significantly related to the later self-reported internalising scores. However, the study does lend support to the suggestion that low levels of emotion understanding in young children, increases the risk of later developing internalising mental health symptoms. Fine et al. (2003) suggest that poor emotion understanding results in misinterpretations of social situations, resulting in isolation, sadness and withdrawal – over time developing into internalising symptoms.

Table 4

Studies with Children under 4 years: Summary of Findings (two population studies only)

Ref	Paper (clinical or population study)	Emotion understanding task	Mental health symptom measure (completed by, symptom measured)	Relationship between emotion understanding & mental health	Other factors significantly associated with emotion understanding
14	Ensor & Hughes, 2005 (Population)	AKT	SDQ – only prosocial subscale reported (parent, prosocial)	Not analysed	Verbal ability Prosocial behaviour
37	Leerkes, Paradise, O'Brien, Calkins, & Lange, 2008 (Population)	AKT	CBCL & Other: Children's Behaviour Questionnaire CBQ-Short (parent, internalising & externalising)	No (affective perspective taking not significantly correlated with CBCL)	Cognitive understanding Cognitive control Emotional control Academic performance

Table 5

Studies with Children aged 4 years: Summary of Findings (5 clinical, 15 population studies)

Ref	Paper (clinical or population study)	Emotion understanding task	Mental health symptom measure (completed by, symptom measured)	Relationship between emotion understanding & mental health	Other factors significantly associated with emotion understanding
6	Martin, Williamson, Kurtz-Nelson, & Boekamp, 2015 (Clinical)	AKT	CBCL & Other: Diagnostic Infant and Preschool Assessment DIPA (Parent, Internalising & Externalising & Psychopathology)	Yes – children with more severe externalising symptoms were less accurate at identifying sadness and fear (not internalising or with other emotion understanding subscales)	Age Language Skills Gender Maternal depressive symptoms
9	Fox, Warner, Lerner, Ludwig, Ryan, Colognori, Lucas, & Brotman, 2012 (Clinical)	Verbal vignettes (Preschool Emotion Interview PEI)	Diagnosis, Other: Spence Preschool Anxiety Scale SPAS & Other: Pediatric Anxiety Rating Scale PARS (Clinician & Parent, Anxiety)	Not analysed (although after intervention anxiety had decreased and emotion understanding had increased)	Not stated
13	Ramos-Marcuse & Arsenio, 2001 (Clinical)	Other: Moral MacArthur Story Stem Battery Moral MSSB	TRF (Clinician or Teacher, Internalising & Externalising)	Yes – required emotion prompts and externalising (but not internalising, no significant difference between Control and Clinic group)	Age Expressive language Attachment Teacher/therapist relationship conflict
18	Hughes, Dunn, & White, 1998 (Clinical)	AKT	SDQ and Other: Interview (Parent & Teacher, Hyperactivity and Behaviour Problems)	Yes – H2M group significantly delayed emotion understanding. Poorer affective perspective taking even when age, verbal ability and family factors taken into account	Age Verbal ability Executive functioning (H2M group) Mother's education (control group)

35	Hughes, White, Sharpen, & Dunn, 2000 (Clinical)	AKT	SDQ (Parent & Teacher, Hyperactivity and Behaviour Problems)	No	Not stated
4	Kidwell, Young, Hinkle, Ratliff, Marcum, & Martin, 2010 (Population)	Other: Abner Emotions Interview	CBCL, TRF & Other: Pitter and Patter Puppet Interview (Parent, Teacher & Child, Internalising & Externalising)	Yes – emotion understanding significantly associated with parent- & teacher-report of behavioural difficulties (externalising behaviours) and internalising	Socioeconomic risk Receptive vocabulary Attachment type
7	Piek, Bradbury, Elsley, & Tate, 2008 (Population)	ERS	CBCL (Parent, Internalising subscales only)	No	Verbal IQ (VIQ) Age Performance IQ (PIQ)
10	Miller, Fine, Gouley, Seifer, Dickstein, & Shields, 2006 (Population)	AKT & verbal vignettes	Other: Preschool Behavior Questionnaire PBQ (Teacher, Anxiety & Aggression subscales)	No	Verbal ability Age Emotion regulation
11	Huang, Cheng, Calzada, & Brotman, 2012 (Population)	Verbal vignettes (Preschool Emotion Interview PEI)	Other: Behavioral Assessment System for Children BASC-2 & Other: Preschool Anxiety Scale PAS (Parent, Child, Anxiety & Depression)	Yes – emotion knowledge and understanding meaningfully related to BASC-2 scales of anxiety and somatisation (not depression)	Not stated
19	Shields, Dickstein, Seifer, Giusti, Magee, & Spritz, 2001 (Population)	Verbal vignettes	Other: Preschool Behavior Questionnaire PBQ (Teacher, Behaviour Problems subscale only)	Not analysed	Age Classroom adjustment
22	Garner & Lemerise, 2007 (Population)	Drawn vignettes	Other: Social Competence and Behavior Evaluation SCBE-30 (Teacher, Internalising & Externalising)	Yes – global emotion situation knowledge and internalising behaviour (not externalising)	Problem solving response decisions Physical victimisation

24	Smith, 2001 (Population)	Verbal vignettes	TRF (Teacher, Other: Social Withdrawal & Peer Social Problems combined for a Social Problems score)	Yes – emotion knowledge and social problems (which includes social withdrawal)	Social Competence Behavioural regulation Peer acceptance Empathy Emotionality trait Delay of gratification Conflict management
26	Laible, 2004 (Population)	AKT	Other: Children’s Behaviour Questionnaire CBQ & Other: Child’s Behaviour Scale CBS (Parent, Prosocial subscale only from CBS & Negative Emotionality)	Yes – emotion understanding and behavioural internalisation	Age Attachment security Effortful control Maternal elaboration during reminiscing Mother-child talk about positive emotion Positive representations of relationships Prosocial behaviour
27	Alonso-Alberca, Vergara, Fernandez-Berrocal, Johnson, & Izard, 2012 (Population)	Verbal vignettes (Emotion Matching Task EMT)	Other: Behavior Assessment System for Children BASC-2 (Teacher, Internalising & Externalising & Adaptive Abilities)	Yes – EMT scores and teacher-rated externalising problems & adaptive abilities (not internalising problems)	Age Verbal ability Gender
28	Bassett, Denham, Mincic, & Graling, 2012 (Population)	AKT	Other: Social Competence and Behavior Evaluation SCBE-30 (Teacher, Internalising & Externalising)	No	Teacher-report of school readiness Emotion recognition Sensitive/cooperative scores

30	Denham, Bassett, Mincic, Kalb, Way, Wyatt, & Segal, 2012[1] (Population)	AKT	Other: Social Competence and Behavior Evaluation SCBE-30 (Teacher, Conduct Problems & Anxiety)	Yes – emotion knowledge significantly lower in group defined as ‘Social-emotional learning (SEL) risk’ – had higher Kindergarten angry/aggressive and anxiety/withdrawn scores (no significant differences by SEL cluster with preschool measures)	Sensitive/cooperative scores Gender
31	Denham, Bassett, Way, Mincic, Zinsser, & Graling, 2012[2] (Population)	AKT	Other: Social Competence and Behavior Evaluation SCBE-30 (Teacher, Anxiety & Anger)	Yes – emotion understanding related to current school adjustment & predicted future school adjustment (SCBE-30 used as part of school adjustment aggregate score)	Age Economic status Emotion regulation Executive function Academic success
33	Dunn, Cutting, & Demetriou, 2000 (Population)	AKT	SDQ & Other: Colorado Childhood Temperament Inventory CCTI (Parent & Teacher, Hyperactivity & Prosocial subscales only from SDQ, Negative Emotionality)	Not analysed	Moral justifications
36	Morgan, Izard, & King, 2009 (Population)	AKT, Verbal vignettes (Emotion Matching Task EMT) & Other: Kusche Emotional Inventory KEI	TRF (Teacher, Internalising & Externalising)	Yes – EMT score and teacher-rated childhood behaviour problems significantly correlated (but EMT did not significantly predict behaviour problems)	Verbal ability Age Emotion regulation Observed adult and peer negative interactions Parent-reported effortful control
38	Dunn & Cutting, 1999 (Population)	AKT	SDQ & Other: Colorado Childhood Temperament Inventory CCTI (Parent & Teacher, Hyperactivity & Prosocial subscales only from SDQ, Negative Emotionality)	Not analysed	Cooperative pretend play turns Talking to friends Observed child conflict behaviour

Table 6

Studies with Children aged between 6 and 9.9 years: Summary of Findings (five clinical, four population studies)

Ref	**Paper (clinical or population study)**	**Emotion understanding task**	**Mental health symptom measure (completed by, symptom measured)**	**Relationship between emotion understanding & mental health**	**Other factors significantly associated with emotion understanding**
23	MacQuiddy, Maise, & Hamilton, 1987 (Clinical)	Drawn vignettes (Parent-child Affective Perspective Taking Scale PCAPS)	Other: Eyberg Child Behavior Inventory ECBI (Parent, Behaviour Problems)	No – only non-significant differences observed between the BP and control group (parent emotion identification, child emotion identification and intensity of character's emotion)	Not stated
32	Downs & Smith, 2004 (Clinical)	Drawn vignettes	Diagnosis (Clinician, Conduct Problems)	Yes – ADHD+ODD group significantly fewer correct answers on emotion understanding task than control group (trend toward significantly lower level of emotion understanding than ASD and Control group)	Not stated
34	Hughes & Dunn, 2000 (Clinical)	Verbal vignettes	SDQ (Parent & Teacher, Hyperactivity and Behaviour Problems)	No – H2M group significantly different attribution of emotions in moral stories versus control, but accounted for by verbal and false-belief comprehension, and no significant difference in emotion understanding task	Verbal ability False-belief performance

20	Woodworth & Waschbusch, 2008 (Clinical)	Verbal vignettes	Other: Disruptive Behaviour Disorder Rating Scale DBDRS & Other: Antisocial Process Screening Device APSD (Parent & Teacher, Conduct Problems & Callous Unemotional Traits)	No (although significant association with accuracy of labelling sad facial expressions and callous unemotional traits)	Age
15	Arsenio & Fleiss, 1996 (Clinical)	Drawn vignettes	Diagnosis (Clinician, Conduct Problems)	Yes – no correct answer for the emotion understanding task, but BD and Control groups differed in the emotional consequences they selected	Age
21	Dodge, Laird, Lochman, Zelli, & The Conduct Problems Prevention Research Group, 2002 (Population)	Verbal vignettes (Emotion Recognition Questionnaire ERQ)	CBCL, TRF & Other: Teacher's Observations of Child Adaptation TOCA-R, Other: Parent Daily Report PDR, Other: Parent Checklist PCL (Parent & Teacher, Behavioural Problems)	Yes – emotion understanding & later teacher-rated aggression. Emotion understanding exerted a highly significant effect on later aggression. Kindergarten understanding of others' fear and sadness (not anger) correlated significantly with 3rd grade teacher-rated aggression. Understanding of others' anger and sadness (not fear) correlated significantly with parental report of aggression	Social information processing factors (tendencies to make hostile biases, to generate aggressive solutions, to evaluate aggression outcomes positively and to opt for instrumental goals)
17	Fine, Izard, Mostow, Trentacosta, & Ackerman, 2003 (Population)	Verbal vignettes	TRF, Other: State-Trait Anxiety Inventory STAI-C & Other: Differential Emotions Scales DES-IV & Other: Children's Depression Inventory CDI (Teacher & Child, Internalising & Externalising, Anxiety & Depression, Negative Emotionality)	Yes – emotion knowledge and teacher-rated internalising (but not externalising), and later self-reports of internalising	Expressive vocabulary

8	Cummins, Piek, & Dyck, 2005 (Population)	ERS	CBCL (Parent, only Social Problems subscale analysed)	Not analysed	Motor disorder (linked to facial expression recognition and unexpected outcomes tasks)
12	Raimundo, Marques-Pinto, & Lima, 2013 (Population)	Other: Assessment of Children's Emotions Scales ACES	TRF & Other: State-Trait Anxiety Inventory STAI-C (Teacher & Child, Social Problems subscale only & Anxiety)	Not analysed (although after intervention emotion understanding had increased and behaviour problems had reduced – anxiety unaffected)	Time (Age: intervention and control groups both increased in emotion understanding)

Table 7

Studies with Children aged between 10 and 12.9 years: Summary of Findings (five clinical, two population studies)

Ref	**Paper (clinical or population study)**	**Emotion understanding task**	**Mental health symptom measure (completed by, symptom measured)**	**Relationship between emotion understanding & mental health**	**Other factors significantly associated with emotion understanding**
25	Termini, Golden, Lyndon, & Sheaffer, 2009 (Clinical)	Verbal vignettes	Diagnosis (Clinician, Reactive Attachment Disorder RAD)	No differences found between the groups (although only RAD group children selected 'neutral' as protagonist's response to transgressions)	Not stated
1	Buitelaar & van der Wees, 1997 (Clinical)	Drawn vignettes	Diagnosis for clinical groups & TRF for control (Clinician & Teacher, Conduct Problems & Depression)	Not analysed (PsCON group analysed together with AUT and NOR groups)	First-order ToM Second-order ToM
3	Dyck, Ferguson, & Shochet, 2001 (Clinical)	ERS	Diagnosis & Other: Children's Anxiety Scale & CBCL for NPD group (Clinician & Child, Anxiety)	No – AnxD children did not differ from the NPD children on emotion understanding scales	Intelligence IQ ToM
16	Buitelaar, van der Wees, Swaab-Barneveld, & van der Gaag, 1999[1] (Clinical)	Drawn vignettes	Diagnosis for clinical groups & TRF for control (Clinician & Teacher, ADHD, Conduct Problems & Depression)	No (although when PsCON, PPDNOS and AUT analysed together, they performed significantly worse than NOR group on emotion understanding tasks – when PsCON compared to NOR no significant difference when ADHD removed)	PPDNOS diagnosis Autism diagnosis ADHD diagnosis

29	Buitelaar, van der Wees, Swaab-Barneveld, & van der Gaag, 1999[2] (Clinical)	Drawn vignettes	Diagnosis (Clinician, ADHD, Conduct Problems & Depression)	No – emotion understanding did not markedly differ across the 3 diagnostic groups	Verbal memory Performance IQ Verbal mental age Age Verbal IQ Gender First-order ToM Second-order ToM
5	Cunningham, Kliewer, & Garner, 2009 (Population)	Verbal vignettes	CBCL, Other: Child Depression Inventory CDI & Other: Revised Children's Manifest Anxiety Scale RCMAS (Parent & Child, Internalising & Externalising, Anxiety & Depression)	No – emotion understanding mediated the association between meta-emotion philosophy and changes in boys internalising symptoms, but this was linked to emotion control	Parent meta-emotion philosophy (awareness, acceptance and coaching) Household income Social skills
2	Williams, Daley, Burnside, & Hammond-Rowley, 2010 (Population)	Other: Story Stems based on MacArthur Story Stem Battery MSSB & Other: Emotion Focusing Task EFT	Other: Beck Youth Inventories of Emotional and Social Impairment BYI (Child, Anxiety, Depression, Anger & Behaviour Problems)	No	Not stated

Question 1: Do children with mental health symptoms show different levels of emotion understanding compared to their healthy peers?

Overall, the evidence is mixed: 16 articles found a link between emotion understanding and mental health symptoms, 14 reported no link and 8 did not report an analysis of this relationship.

Table 8 shows the presence of a link by age group. The majority of studies reporting a link took place in the USA, whereas the majority of studies reporting no link took place outside of the USA. The majority of studies looking specifically at low income groups reported a link (all took place in the USA). A link was reported in 5 of 13 clinical studies, and in 11 of 17 population studies. This appears to suggest that evidence for a link is strongest in USA-based population studies of younger school children and decreases with age.

Table 8

Reporting of Emotion Understanding and Mental Health Symptom Link by Age Group

Age group	**Number of studies reporting a link (%)**	**Number of studies reporting no link (%)**
Under 4 years	0 (0)	1 (100)
4 years	12 (75)	4 (25)
6 – 9.9 years	4 (57)	3 (43)
10 – 12.9 years	0 (0)	6 (100)

Approximately equal numbers of studies reporting a relationship and reporting no relationship used each of the emotion understanding tasks, although both studies using the ERS reported no relationship. This suggests that no one task has a bias creating or obscuring any association. In conclusion, the evidence of a link between emotion understanding difficulties and mental health symptoms is mixed, appearing strongest in population studies of 4 year olds.

Question 2: Are differences in emotion understanding consistent across different types of mental health symptoms?

Five of the seven studies which used diagnosis (all clinical studies) reported no relationship. All but one of the studies which used the TRF reported a relationship – and the study which did not report a relationship, used the TRF only as a screening measure for the control group. Eleven of the 17 studies using teacher-report found a link, predominantly in studies of 4 year olds, whilst other informants had similar numbers of studies that reported a link as reported no link. Approximately equal numbers of studies using multiple informants reported a link as reported no link. As the TRF questions map closely to the CBCL parent-report measure, this suggests that teacher's estimates of mental health difficulties (known to be more accurate for externalising symptoms) relate more closely to emotion understanding than parent's reports, particularly for younger children.

Table 9 shows the presence of a link by mental health symptom. Four studies that reported both externalising and internalising symptoms found externalising symptoms (but not internalising symptoms) to be significantly linked to emotion understanding, while two studies reported the reverse pattern. None of the studies looking specifically at depression found any evidence of a link with emotion understanding, whereas 50% of the studies looking specifically at anxiety did show a link. It is possible that the inclusion of depression in broad-band assessments of internalising disorders may mask a link with anxiety disorders. The results suggest that the pattern of relationships between mental health symptoms and emotion understanding is different for different mental health conditions.

Table 9

Reporting of Emotion Understanding and Mental Health Symptom Link by Mental Health Symptom

Mental health symptom	**Number of studies reporting a link (%)**	**Number of studies reporting no link (%)**
Both internalising and externalising symptoms	7* (70)	3 (30)
Externalising disorders/conduct problems/behavioural problems	5 (42)	7 (58)
Internalising disorders unspecified	4 (33)	8 (67)
Anxiety	4 (50)	4 (50)
Depression	0 (0)	6 (100)

*Mostly in the age 4 group

Question 3: Do differences in emotion understanding increase the risk of later developing mental health symptoms?

Of the nine longitudinal studies that reported on the relationship between emotion understanding and mental health, one (Smith, 2001) reported only on mental health and emotion understanding measures taken at a single time point (only sociometric measures were taken at a later time point) and so cannot be considered a longitudinal study for the purpose of this review. Of the remaining eight studies, four found a relationship (50%): two were linked samples and two were longer-term studies with a gap of several years.

Emotion understanding the year before kindergarten was used to create social emotional learning (SEL) groups. The SCBE-30 was administered that year and again in kindergarten. The only relationship found between the SEL groups and the pre-kindergarten SCBE scores was the sensitive/cooperative scale (not a mental health symptom scale), but the later kindergarten measures found significant SEL group differences for the angry/aggressive and anxious/withdrawn scores (Denham et al., 2012[1]). Emotion understanding was then found to link with a measure of school adjustment (which included the mental health measure) rated at the same time and also to predict future school adjustment the following school year (Denham et al., 2012[2]).

In the longer-term studies, kindergarten emotion understanding scores had a highly significant effect on aggression rated three years later (Dodge, Laird, Lochman, Zelli, & The Conduct Problems Prevention Research Group, 2002), and (as discussed above) emotion understanding aged 7 years significantly predicted self-reported internalising symptoms completed 4 years later (Fine et al., 2003).

Four longitudinal studies reported no relationship between mental health symptoms and emotion understanding. Bassett et al. (2012) was part of the same investigation as the two linked sample studies detailing a relationship above (Denham et al., 2012[1]; Denham et al., 2012[2]), but analysed data from two time points in the year before kindergarten (and so found emotion understanding was only predictive of sensitive/cooperative scores, but not of either of the mental health symptom scores). Hughes and Dunn (2000) reported significant group differences between the 'hard to manage' and control group: with differences in emotion attribution in moral stories, but verbal ability and false-belief comprehension accounted for the group difference, and emotion understanding was not reported to be significantly different between the groups.

The remaining two studies reporting no relationship took initial measures when children were aged 10 or above (Cunningham, Kliewer, & Garner, 2009; Williams, Daley, Burnside, & Hammond-Rowley, 2010), whereas the studies reporting a relationship all took their first measures before the age of 8. This supports the idea that early emotion understanding difficulties may be predictive of later mental health symptoms, both internalising and externalising. It also suggests that although co-timed measures may not initially indicate a relationship, this may become apparent when later mental health measures are completed.

Potential Moderating and Mediating Factors

Demographics. Age was commonly reported as having a significant link (in 14 studies), with older children scoring more highly on emotion understanding tasks than younger children. A significant effect of age on emotion understanding was reported in 50% of the studies in the 4 year old age group, a key age in the development of emotion understanding. Four studies also reported a link with gender: with boys showing a greater anger bias (a tendency to incorrectly identify non-anger emotional cues as anger), scoring lower on emotion understanding tasks, a lower proportion of boys passing emotion understanding tasks, or more boys being allocated to a social emotional learning at risk group. It may be that boys develop emotion understanding skills later than girls.

Prosocial skills. Ten population studies reported a link between emotion understanding and a variable linked to prosocial skills or peer relationships. Higher levels of emotion understanding were significantly linked with more prosocial behaviour, peer acceptance, cooperative pretend play, social skills and sensitive/cooperative scores. This is a possible mediating factor of the impact of emotion understanding on mental health symptoms as lower peer acceptance and fewer positive social relationships may result in isolation, withdrawal and internalising symptoms. Better emotion understanding was shown to relate to lower levels of observed negative interaction with peers (Morgan, Izard, & King, 2009), but surprisingly was also shown to predict higher rates of physical victimisation (Garner & Lemerise, 2007).

Attachment. Three studies reported links between emotion understanding and attachment: securely attached children scored more highly than children with insecure attachments (Laible, 2004), children with higher attachment scores required fewer prompts (Ramos-Marcuse & Arsenio, 2001), and children with aggressive/feigned helplessness subtype of insecure-coercive attachments scored lower than children with secure attachments (Kidwell et al., 2010). Insecure attachments have been shown to significantly contribute to later mental distress (Mikulincer & Shaver, 2012). Potentially, emotion understanding is a moderating factor affecting the strength of the relationship between attachment and mental well-being.

Emotional regulation. Four studies, all in the youngest two age groups, found a positive association between emotion understanding and emotion regulation. All of these studies used the AKT, two in combination with verbal vignettes, none of which include an emotion control or self-emotion recognition element. This suggests that the ability to recognise and understand your own emotions (skills necessary for emotion regulation) may develop in parallel to, or be part of the same process of, recognising and understanding others' emotions.

Language ability. Higher levels of language ability were linked to better emotion understanding in 12 studies: this might reflect the language requirements of the emotion understanding tasks, particularly verbal vignette tasks where no visual cues are available (used in 5 of these studies), however it may also suggest a link between these developmental tasks.

Cognitive abilities. Four clinical studies reported that emotion understanding was positively correlated with ToM ability: including false-belief performance, first- and second-order ToM. As affective perspective taking tasks used to study emotion understanding require the child to be able to consider another's perspective, ToM skills may aid performance in emotion understanding tasks.

Studies also found links between emotion understanding and measures of IQ (including performance, verbal and overall IQ), executive functioning, effortful control and academic performance. All of these were positive relationships, with the exception of one study (Hughes, Dunn, & White, 1998) which found that executive functioning had a negative correlation with emotion understanding in the clinical behavioural problem group. Verbal ability was then partialed out, resulting in a significant positive correlation for the control group, and a non-significant negative correlation for the behavioural problem group.

Cognitive skills may aid performance in emotion understanding tasks as they allow the child to:

- take in and process visual information (required in the AKT, drawn vignette and FET tasks);
- hold information in working memory (particularly required in the verbal vignette tasks);
- comprehend and respond to task instructions and questions (required across all tasks, but particularly in the EVT task);
- reason and problem solve (as required in the equivocal stories in the AKT and the UOT task); and
- manage attention during testing (required across all tasks).

Academic performance is likely to be reflective of these underlying cognitive abilities, and therefore also to correlate with emotion understanding abilities. However, these correlations could also suggest parallel developmental processes in different areas of cognition and emotion understanding.

Discussion

Summary of Findings

Of the 38 papers reviewed: 16 reported a link between emotion understanding and mental health, 14 reported no link, and 8 did not report an analysis of this relationship. The majority of studies reporting a link were population-based studies carried out with younger school children. Teacher-report of mental health symptoms appeared to relate more closely to emotion understanding than reports from other informants. Although the evidence is not conclusive, there appears to be some support for the idea that children with mental health symptoms show more difficulties with emotion understanding compared to healthy peers.

The evidence of a relationship with emotion understanding is stronger for externalising than internalising symptoms. There is no evidence for a link with depression and the inclusion of depression in broad-band assessments of internalising symptoms may mask a link with anxiety. This suggests that the relationship between emotion understanding and mental health is not consistent across different types of mental health symptoms.

Longitudinal studies provide limited evidence that early emotion understanding deficits predict later internalising and externalising symptoms, even if concurrent mental health measures do not indicate a relationship. Lower levels of emotion understanding in younger children appear to increase the risk of later developing mental health symptoms.

Prosocial behaviours and peer acceptance appear related to levels of emotion understanding and may be mediating factors between emotion understanding and mental health symptoms. Language skills and cognitive ability appear related to emotion understanding, but this may partly be the result of the verbal and cognitive demands of emotion understanding tasks. Four studies reported that girls demonstrated more advanced emotion understanding, suggesting they may develop this ability earlier than boys. Age was widely reported as a link with emotion understanding, fitting with the premise of emotion understanding as a skill that develops across this age range. Emotional regulation was also linked with emotion understanding and may develop in parallel, or as part of the same developmental process as affective perspective taking.

Comparison with Previous Research

The previous meta-analysis (Trentacosta & Fine, 2010) reported small to medium mean effect sizes (r = -.17) for emotion understanding and internalising problems, and for emotion understanding and externalising problems. Effect sizes for each study were not given, so it is not possible to see if any of the studies included in the meta-analysis reported no relationship between emotion understanding and mental health symptoms. However, this review found that only 53% of studies analysing the relationship found a significant link, suggesting the evidence now is perhaps less conclusive. This review has focused on the younger age group, and the meta-analysis reported strongest evidence in older children (preadolescents and adolescents), which could explain the more mixed results reported here.

In contrast to the meta-analysis, which found larger effects in clinical populations, this review found evidence of a link in only 38% of clinical studies, versus 64% of population studies. This may be explained by the lower numbers of clinically diagnosed children in the younger age group studied by this review. The stronger relationship with externalising (rather than internalising) disorders found in the meta-analysis has been replicated here. Following the recommendation in the meta-analysis, anxiety and depression were analysed separately where possible: results suggest that anxiety may be related to emotion understanding, but found no evidence that depression is specifically related. This could account for the mixed results in studies measuring internalising difficulties as a single category. However, only six studies reported depression separately and so caution must be taken in the interpretation of this finding.

Limitations

Both emotion understanding and mental health symptoms are very broad concepts and many terms are used for each. It is complicated to search for these concepts and although a thorough list of search terms were used, it is likely that some relevant studies may have been missed through the use of alternative descriptors. A wide range of methodologies was used to assess slightly different aspects of emotion understanding abilities and diverse mental health symptoms. The studies also had different aims and so were not easily comparable. These factors limit the possible interpretations of the results of this review.

At times, mental health symptom ratings were combined with other factors to produce more general adjustment or problem scores, or although mental health symptom measures were used and reported on, none of the sample reached the clinical threshold. The emotion understanding tasks frequently result in a composite measure of multiple aspects – for example, combining recognition with perspective taking – or involve tasks where recognition and/or perspective taking can be used to answer (e.g.: the AKT). This may mask any effects of just one component. For example, it has been theorised that a link between social anxiety and emotion understanding may be the result of lower levels of eye contact in socially anxious children, limiting their exposure to facial cues (McClure & Nowicki, 2001). If this theory is correct then according to the developmental phases posited by Pons et al. (2004), lower levels of facial emotion recognition would be expected, with average levels of affective perspective taking. Contrastingly, if the 2-factor structure proposed by Bassett et al. (2012) is correct, both areas may be affected as recognition is seen as a pre-requisite for affective perspective taking. However, it is possible that there might be a specific deficit in facial emotion recognition but not in vocal emotion recognition.

It is also possible that understanding of specific emotions differentially affects mental health symptoms. For example, Dodge et al. (2002) reported that understanding of others' fear and sadness (but not anger) was significantly correlated with later teacher-reported aggression (although understanding of others' sadness and anger (but not fear) was significantly correlated with later parental report of aggression). This possible effect of understanding specific emotions is reinforced by the later finding that children with severe externalising symptoms were less accurate than children with other emotional difficulties, at identifying sad and fearful expressions, but not happy or angry expressions (Martin, Williamson, Kurtz-Nelson, & Boekamp, 2015). As the emotion understanding tasks commonly take an overall measure of a type of emotion understanding (e.g.: recognition or affective perspective taking) across different emotions (e.g.: happy, sad, angry and scared), the impact of a specific deficit in one or two emotions could be missed.

The majority of studies were cross-sectional and so could not make implications regarding causation. There is some evidence from a small number of longitudinal studies that a child's level of emotion understanding can predict later levels of internalising or externalising symptoms, but more research would be needed to investigate this further. Verbal and cognitive abilities were shown to be significantly correlated with emotion understanding in many of the studies. The different emotion understanding tasks require verbal skills in addition to attention, working memory, reasoning and visual processing abilities. It may be that levels of emotion understanding are higher than the results suggest, but are limited by the requisite verbal and cognitive skills.

Implications

As recommended by Trentacosta and Fine (2010), it is still the case that further research is needed, particularly with studies reporting emotion understanding for individual emotions separately to investigate possible effects of bias in processing specific emotions, and also reporting separately on subtypes of internalising disorder. This review was unable to identify any studies with a mean sample age of 5 years old. As this is the age when the first stage of emotion understanding is proposed to be achieved (Pons et al., 2004), this would seem to be a key population to investigate.

The development of a validated emotion understanding test for younger children which does not rely on a combination of emotion recognition and affective perspective taking (as in the AKT where a situation is given together with facial and verbal emotion cues) would allow the contributions of recognition versus perspective taking to be evaluated. If such a test was able to reduce the verbal abilities required to complete it, this would potentially reduce any limiting effect of language skills.

Further longitudinal research is needed to establish whether emotion understanding deficits can reliably predict future internalising and externalising symptoms, ideally using multiple-informant report of symptoms. Longitudinal studies with repeated measures of emotion understanding and mental health symptoms could also allow investigation of whether emotion understanding differences are stable before, during and after recovery from mental health symptoms, or whether a deficit at a young age is resolved but remains predictive of later mental health difficulties. Longitudinal studies may also allow investigation of peer acceptance as a potential mediator of the relationship between emotion understanding and mental health.

If emotion understanding deficits are found to reliably predict later mental health symptoms, then emotion understanding screening may be advisable in young children. Preventative interventions to enhance emotion understanding have already been trialled: for example, the PATHS curriculum (Greenberg, Kusche, Cook, & Quamma, 1995) and the social-emotional intervention outlined by Denham and Burton (1996). These have shown improvements in elements of emotion understanding and social problem solving, increased prosocial skills and reduced negative emotions. Studies have already started to evaluate the impact these programmes have on child mental health symptoms in subsequent years. Although findings are mixed, there are indications that preventative emotion understanding programmes such as PATHS can potentially have a positive effect on externalising behaviours over a 4 year period (Malti, Ribeaud, & Eisner, 2011). It would be helpful for further evaluation of the impact of these interventions to consider disorder-specific mental health symptoms. Current child mental health treatments should also be evaluated to assess whether too high a level of emotion understanding is assumed, and whether the addition of basic emotion skills would increase their efficacy.

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Part 2: Empirical Paper

Exploring Children's Emotion Understanding through EEG Measurement of Neural Correlates and a Standard Emotion Understanding Task

Abstract

Aims

This study aimed to replicate Bennett's (2013) finding that the presence of a late positive potential (LPP) when viewing stories with emotionally incongruent outcomes can be used as an index of emotion understanding. Further, it aimed to compare the LPP index of emotion understanding with a self-report measure of emotion understanding, and investigate whether the LPP is a specific neural correlate of emotion understanding.

Methods

43 children between 5 and 8 years old undertook an EEG task involving stories with congruent and incongruent emotion outcomes, and expected and unexpected physical outcomes. They also completed the test of emotion comprehension (TEC; Pons & Harris, 2000) and parent-report questionnaires were collected.

Results

Bennett's (2013) finding of a larger LPP for incongruent outcomes was replicated, but found in both emotionally and physically incongruent conditions: allowing an interpretation of the LPP as a neural index of contextual incongruity detection or processing, but not as a specific neural correlate of emotion understanding per se. A significant effect of story type (emotion or physical) was found on LPP latency (later for physical conditions), P3 amplitude (larger for physical conditions) and N1 amplitude (larger for emotion conditions). No significant correlation was found between TEC scores and ERP components.

Conclusions

There is strong evidence for a neural index of emotion understanding which can be used to assess affective perspective taking ability. As a brain-based measure it may also allow more accurate assessment of emotion understanding skills, with less reliance on language than traditional self-report measures, and could be extended to investigate neural differences in affective perspective taking in ASD populations.

Introduction

Emotion understanding is a key developmental process, impacting on social skills and relationships. Children's understanding of emotions has been tested in a variety of ways and is important in assessing typical child development timelines. Bennett (2013) suggested that the presence of a late positive potential (LPP) when viewing stories with emotionally incongruent outcomes, could be used as an index of emotion understanding. This study aimed to replicate this initial finding, compare the LPP index of emotion understanding with a standard measure of emotion understanding, and investigate whether the LPP is a specific neural correlate of emotion understanding.

Emotion Understanding

Emotion understanding can be used to describe a wide group of abilities including recognition of facial expressions of emotions, emotional self-regulation and the ability to understand another's emotions given a certain context. This study focuses on the last of these, namely affective perspective taking. This affective ability is similar to cognitive theory of mind (ToM), which is the capacity to attribute beliefs and intentions to others. Studies have shown that these two aspects of social development are significantly related (Harwood & Farrar, 2006), yet are also distinct skills (Cutting & Dunn, 1999). Most recently, O'Brien et al. (2011) demonstrated that emotion understanding develops first and predicts later developing ToM skills, suggesting that affective perspective taking can aid and inform developing cognitive perspective taking skills.

Two developmental pathways of emotion understanding have been proposed: a three developmental phase model (external, mental and reflective phases; Pons, Harris, & de Rosnay, 2004) and a two-factor structure (recognition of expressed emotion and understanding of context-dependent emotions; Bassett, Denham, Mincic, & Graling, 2012). The former proposes that recognising emotional expressions and understanding emotions from external causes develop together as the first phase at around 5 years of age, whilst the latter suggests these two elements are related but distinct – with recognition a pre-requisite for the development of affective perspective taking. Pons et al. (2004) describe the later phases as understanding desire or belief-based emotions and hiding emotions (at around 7 years) and then understanding mixed emotions and the impact of morals (around 9 to 11 years). By focusing on affective perspective taking rather than recognition, this study aims to capture the more complex of the emotion understanding skills.

Longitudinal studies of emotion understanding have shown that children's level of emotion understanding improves with age, but there are also stable individual differences (Pons & Harris, 2005). The level of emotion understanding can be markedly different among children of the same age, and within normal populations some 4 to 5 year old children demonstrated higher levels of emotion understanding than 10 to 11 year olds (Pons, Lawson, Harris, & de Rosnay, 2003). Studies have found significant individual differences in emotion understanding, with language ability and age together explaining 72% of the variance (Pons et al., 2003). This has led to the development of language-based interventions aimed at improving communication about emotions, which preliminary research suggests are effective at increasing emotion understanding (Pons et al., 2003). However, current emotion understanding test paradigms frequently require significant language abilities and therefore may underestimate children's understanding, particularly if they have language difficulties. Brain-based assessments may help to circumvent this problem and may therefore find less variance attributable to language ability.

Emotion understanding is a concept relevant to neurodevelopmental disorders such as Autistic Spectrum Disorder (ASD). Evidence is conflicting regarding deficits in emotion understanding in ASD, but research suggests there may be delays in the development of specific emotion recognition skills (Law Smith, Montagne, Perrett, Gill, & Gallagher, 2010). There is a suggestion that the regions of the brain involved in emotion processing are affected in ASD, and fMRI studies have shown that ASD populations seem to show atypical neural organisation for facial processing including interpretation of expressions of emotion (Philip et al., 2012). The mirror neuron system (MNS) is thought to play a role in emotion understanding through a process of representing another's perspective, and there is evidence of MNS dysfunction in ASD (Philip et al., 2012).

The specific deficits in ToM and emotion understanding observed in ASD suggest that these processes may relate to specific neural networks which are affected in ASD. However, it has also been suggested that atypical neural networks in ASD are not static, and research has shown age-related changes in neural activity for social tasks in children and adults with ASD (Dickstein et al., 2013). Therefore, the neural basis of emotion understanding may develop later in children with ASD, resulting in delayed emotion recognition.

EEG

EEG (electroencephalograms) can be used to identify neural correlates of cognition and behaviour. EEG studies have investigated neural correlates of belief-reasoning: only children who correctly answered false-belief questions showed a negative late slow wave (LSW) similar to the adult response, although adults showed a left-frontal distribution where children showed more diffuse frontal activity (Liu, Sabbagh, Gehring, & Wellman, 2009). Later studies also showed the frontal LSW in belief-reasoning, but with a different polarity (Meinhardt, Sodian, Thoermer, Döhnel, & Sommer, 2011). Based on differences between the two paradigms, Meinhardt et al. (2011) suggested that a negative LSW reflects the generic process of attributing a mental state to another, whereas a positive LSW specifically reflects reasoning that allows attribution of a mental state to another, independent of reality.

EEG has also been used to investigate the brain's response to emotions. When presenting neutral or emotional faces, EEG showed that emotional faces triggered an increased ERP (event related potential) positivity not specific to the emotion shown, suggesting activity in a neocortical system generating representations of emotional content (Eimer & Holmes, 2007).

The late positive potential (LPP) is an ERP component commonly used in the study of emotion. Research has shown that the LPP is larger when an emotional image has been presented compared to a neutral image, and that it persists after image presentation ends (when images were shown for 2000ms) (Hajcak & Olvet, 2008). The LPP has been shown to be larger for more affectively intense emotionally arousing images, regardless of the image valence (Schupp et al., 2000). However, a study using both EEG and fMRI found that the enhanced LPP recorded for emotion eliciting images (versus neutral images) was linked with different brain areas depending on the image valence (Liu, Huang, McGinnis-Deweese, Keil, & Ding, 2012), suggesting that different areas of the brain are responsible for enhanced LPP in response to pleasant images, compared to unpleasant images.

The N400 is a negative deflection shown in studies with a violation of expectation. A study in adults found that when a character's emotional response (presented in words) was incongruent with the preceding context, an N400 response was observed 200-500ms after the incongruent word, in addition to a larger frontal positivity (Leuthold, Filik, Murphy, & Mackenzie, 2012). Larger N400 responses were observed when sentences ended with incongruent rather than congruent words and an impact of valence was also present, with negative emotional words resulting in larger N400 responses than positive or neutral incongruent words (de Pascalis, Arwari, D'Antuono, & Cacace, 2009). The N400 has been theorised as a brain response associated with meaning processing particularly when predictions based on contextual information are disconfirmed (Kutas & Federmeier, 2011).

A larger LPP (but not N400) was shown for evaluatively incongruent compared to congruent pairs of emotional stimuli (Herring, Taylor, White, & Crites, 2011), whilst both LPP and N400 responses were larger when participants read about behaviour inconsistent with previous information given about a character

(Baetens, van der Cruyssen, Achtziger, Vandekerckhove, & van Overwalle, 2011). Together these studies were used to suggest that the N400 increases as greater effort is required to make sense of the inconsistent information, while the LPP may increase as a result of greater attention for evaluatively incongruent information (Baetens et al., 2011).

Finally, the P3 component is a positive deflection from around 300ms after stimulus onset, most pronounced in parietal regions, which has been studied in ToM tasks. Donchin and Coles (1988) developed the contextual updating model which theorises that larger P3 amplitudes reflect larger updates required in the person's existing contextual model, when new relevant information is presented. In ToM tasks a significantly greater late positive complex (LPC), described as 'P3-like' in terms of its latency and distribution, has been found for false- rather than true-belief reasoning: where participants have to consider their knowledge of characters' beliefs (Meinhardt et al., 2011). Meinhardt et al. (2011) suggested the LPC was involved in shifting attention from external stimuli to a character's mental representation, and also reported greater LPC amplitudes when the outcome was unexpected.

Previous Study

Bennett (2013) presented children with stories with emotional outcomes which were either congruent or incongruent. EEG results showed significantly greater LPP responses for incongruent than congruent outcomes, with no significant effect of valence. The absence of congruence effects on early visual processing ERPs supported an interpretation that the LPP difference related to congruency rather than differences in the stimuli's visual properties. Whilst an LPP would be expected for all the stories (as a positive or negative emotion is always portrayed), the greater LLP in incongruent conditions suggests that the emotion was processed as an evaluatively incongruent stimuli.

In contrast, and unlike earlier studies, the N400 component did not significantly differ between congruent and incongruent outcomes, suggesting that it was not a violation of expectation response, and that therefore additional effort was not required to make sense of inconsistent information. This could be taken to suggest that the incongruent emotional outcome was not considered inconsistent. One explanation for this is that emotional responses are not entirely predictable and children may have experienced and accepted that others sometimes show different emotions in similar situations.

The P3 component did not significantly differ, suggesting that incongruent outcomes did not require the child's contextual model to be updated. It may be that as participants were instructed at the start to focus on how the character was feeling they were already focused on the character's mental representation and therefore no shift in attention was required.

Current Study

This study aimed to replicate and extend the results of Bennett's 2013 study. The initial study did not compare EEG results against other traditionally administered tests of emotion understanding and so the test of emotion comprehension (TEC; Pons & Harris, 2000), a commonly used task for assessing emotion understanding, was compared against the neural index of emotion understanding from the EEG task.

The initial study also did not compare incongruent emotional outcomes against other unexpected outcomes. Therefore it concluded that there was a neural index of emotion understanding, but could not confirm that the response shown was a neural correlate specific to emotion understanding. This study used stories with congruent and incongruent emotional outcomes from the initial study, and compared them to stories with expected and unexpected physical outcomes to determine whether this neural feature is a specific correlate of emotion understanding or occurs with any unexpected outcome.

If the EEG paradigm was shown to be effective in assessing a child's emotion understanding (either as a neural index, or specific neural correlate) then a baseline of neurotypical children's emotion understanding could be produced. This could then be compared to emotion understanding in populations with neurodevelopmental disorders, and might identify neural developmental differences in emotion processing in these groups. As a brain-based measure, this task would potentially reduce any limiting effect of language skills and might therefore show higher levels of emotion understanding than traditional tests in populations with reduced language abilities, allowing more accurate assessment of affective perspective taking.

Aims

This study aimed to replicate Bennett's 2013 finding of a neural index of emotion understanding. It aimed to extend these findings by correlating EEG findings with self-report data on emotion understanding using the TEC. It further aimed to clarify if the greater LPP observed in relation to incongruent emotional outcomes was a specific neural correlate of emotion understanding, or an index of emotion understanding which was also present with unexpected physical outcomes. If a specific neural correlate was found suggesting that the LPP was specific to the processing of emotions, then it would be expected that the LPP would only be present in emotionally incongruent stories, whilst the N400 would be found either solely in physically unexpected stories, or also in emotionally incongruent stories indicating a violation of expectation.

Methods

Participants

This cross-sectional study was part of a longitudinal cohort study investigating attachment and psychological functioning. Participants were recruited from a cohort of children between 5 and 8 years old who had taken part in previous EEG or attachment studies as infants at a North London clinical and research facility for children and adolescents.

The following exclusion criteria applied: children who had already been followed up by Bennett (2013), children with visual or hearing difficulties that couldn't be corrected with glasses or hearing aids, children diagnosed with ASD or a learning difficulty, and children with an electronic implant or metal fragment where this causes interference with the EEG.

43 children (18 boys), aged between 62 and 89 months (*M* 76 months, *SD* 8 months) took part in the study. The sample contained mostly children from white, middle-class families. After analysis of the recorded EEG data, the sample with viable EEG data comprised 36 children (15 males), aged between 64 and 89 months (mean and standard deviation remained unchanged: *M* 76 months, *SD* 8 months). See Figure 1 for a flow-diagram of participation.

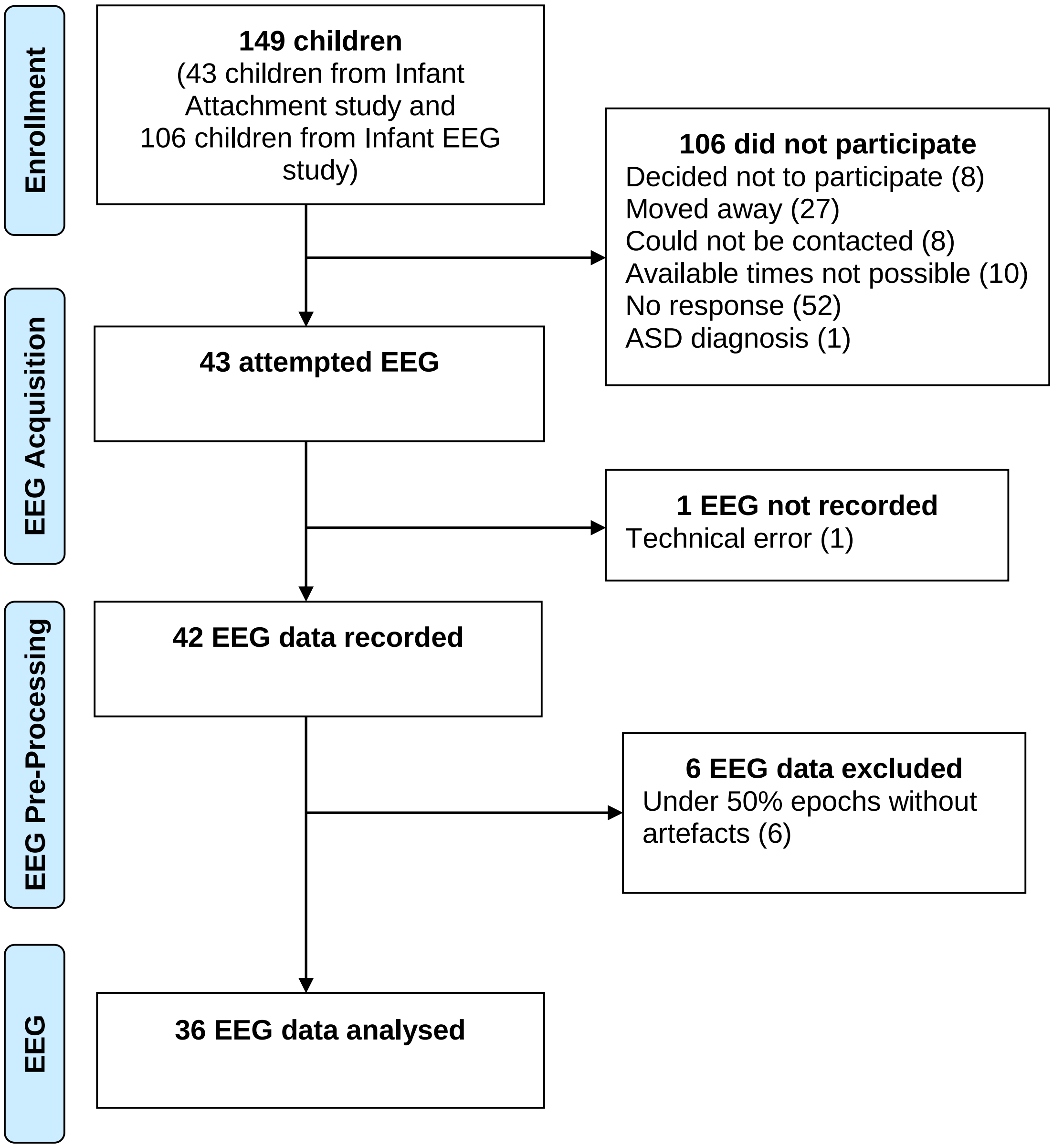


Figure 1. Flow diagram of recruitment and attrition.

Sample Size

Power calculations were used to determine the minimum required sample size. Bennett (2013) reported a significant difference in LLP between congruent and incongruent emotion stories ($F(1,32) = 27.818$, $p < .001$). To detect this effect size ($d = 0.76$) at 80% power and 5% significance, 11 participants were required. As EEG studies with children frequently result in a relatively high proportion of unusable data due to excessive movement artifacts (Meinhardt et al., 2011), the aim was to recruit a minimum of 20 participants, ideally more to allow tests for group differences on the basis of gender to be performed.

Design

Families were initially sent a parent letter, study information sheet and child invitation letter (see Appendices A, B, and C) by post or email which was then followed-up by telephone. When a parent agreed for their child to take part, a confirmation letter was sent together with a consent sheet (see Appendices D and E).

Upon arrival, parents were asked if they had any questions and completed the consent form. The child was asked if they had any questions and the tasks were explained before the child was asked if they would agree to take part. Children were given the opportunity to ask any further questions at the end of the session and were given a £5 book voucher and certificate (see Appendix F) for taking part.

This study comprised EEG and behavioural tasks, and parent-report questionnaire measures during a single testing session lasting approximately two hours. The questionnaires, EEG study and Test of Emotion Comprehension (TEC; Pons & Harris, 2000) are analysed in this report. Two additional tasks (Story Stem Assessment Profile (SSAP; Hodges, Hillman, Stufkens, & Steele, 2014) and Family-Attachment Drawing Task (FAD-T; Fury, Carlson, & Sroufe, 1997)) are not reported here.

As the EEG task required children to sit still and often children were most excited or nervous about this task, it was always carried out first. The tasks were administered in the same order with the two longer tasks first (EEG, SSAP, TEC then FAD-T). Children were given a refreshment break after the EEG task and were offered an additional break after the SSAP if required. Parents stayed with the child while the EEG net was applied, but waited outside the testing room while the child completed the tasks with the researchers.

Measures

EEG task. The EEG task was a revision of the emotion outcome test used by Bennett (2013). The emotion outcome test consisted of 40 stories about male and female child characters. These were told through the use of three or four static drawn colour images with a recorded audio voiceover for all but the final image in each story. The penultimate image showed a child character with a blank face with no features and the voiceover asked the participant: “I wonder how s/he’s feeling?” (see Figure 2 for sample item). The final image was identical to the penultimate one, except that the child character showed either a positive or negative facial expression, which was either congruent or incongruent given the context of the story. Participants were shown 10 stories for each of the 4 conditions: positive congruent, negative congruent, positive incongruent and negative incongruent. Each story had a congruent and incongruent ending, used to create two counterbalanced versions of the task, with stories presented in a random order, showing every participant each story only once.

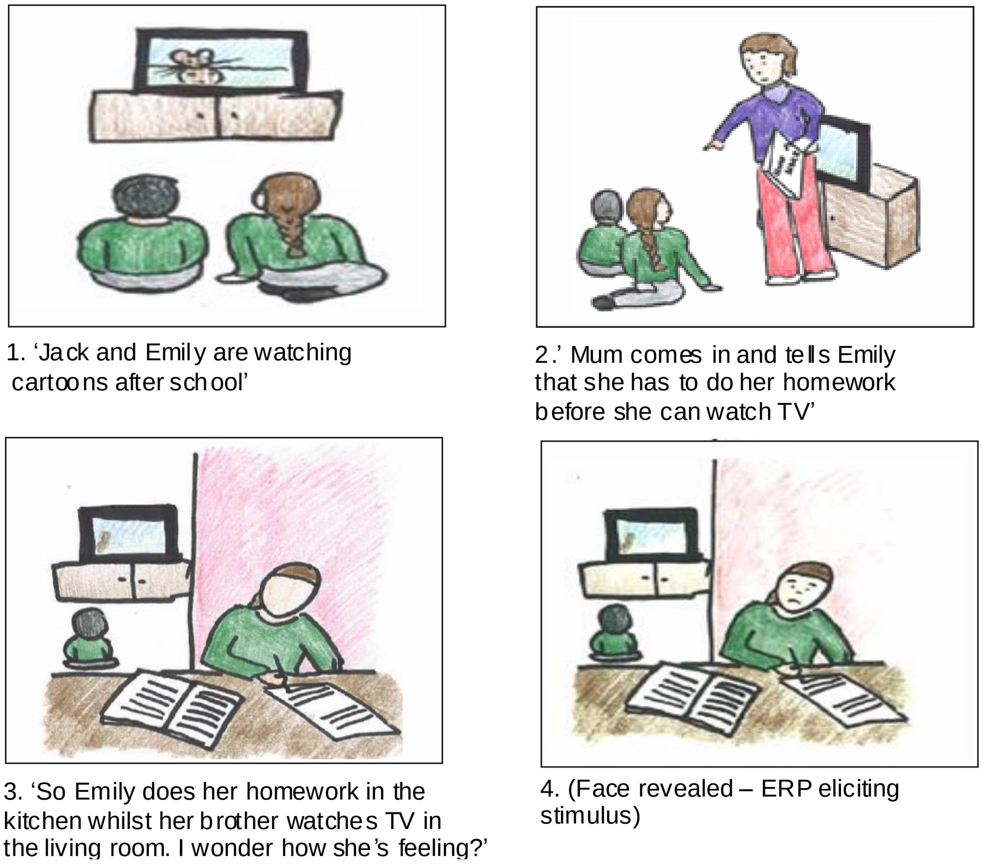


Figure 2. Example of emotion outcome test EEG stimuli (negative congruent example), taken from Bennett (2013).

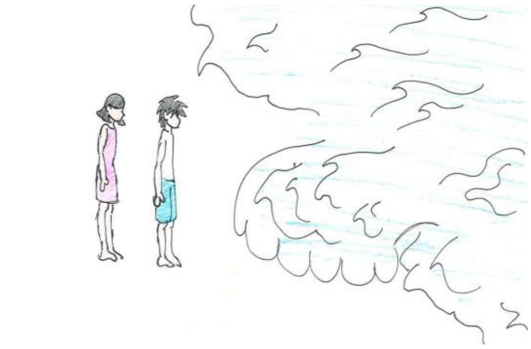
The physical and emotion outcome test used in this study included 24 emotion stories from the original emotion outcome test (12 positive, 12 negative – see Appendix G for story scripts), in addition to 24 physical stories. 24 emotion stories were chosen as it was not practical to ask a child to sit still to watch 40 emotion stories and 40 physical stories. Bennett advised on stories which children had responded well to in the earlier study. Stories where the expected emotion depended on a certain relationship with another character, or which were too close in theme to one of the physical stories were removed. Positive and negative stories were combined to create two conditions – congruent and incongruent – but equal numbers of positive and negative stories were shown in each version of the task.

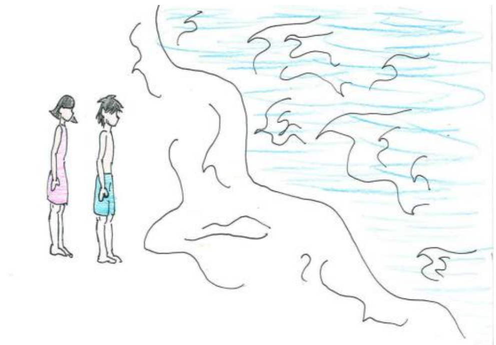
Of the 24 physical stories used, 7 were taken from a set of physical causality stories validated with adolescents by Sebastian et al. (2012), which had been adapted from stories initially developed by Völlm et al. (2006). These were developed to require no understanding of the mental states of the characters (emotional or cognitive), only an understanding of cause and effect. These seven stories were redrawn so they were in colour and featured child characters. A further 17 physical stories were produced which also relied only on an understanding of cause and effect, so that a total of 24 stories were available (see Appendix H for story scripts).

Stories again featured male and female child characters and were presented in an identical fashion to the emotion outcome test, except that the voiceover question for the penultimate image asked: “I wonder what will happen next – shall we see?” (see Figure 3 for sample item). The drawings were similar in style and did not include any facial features, and Bennett provided the voiceovers so they were as close as possible to the original stories. Each physical story had an expected and unexpected outcome which could be clearly illustrated in the final image, which was otherwise identical to the penultimate image.

1. ‘Rosanna and Jim have built a sandcastle’.

2. ‘A wave is coming closer to them’.





3. ‘The wave goes right over their sandcastle.
I wonder what will happen next – shall we see?’

4. (Expected outcome revealed
– ERP eliciting stimulus).

Alternative 4.
(Unexpected outcome revealed – ERP eliciting stimulus).

Figure 3. Example of physical EEG stimuli.

Participants were shown 12 stories for each of the 4 conditions: emotionally congruent, emotionally incongruent, physically expected and physically unexpected. Again two counterbalanced versions of the task were created so that every participant saw each story only once. Because different instructions were needed for the physical versus the emotional task, they were kept separate with all stories of one type shown first, but with a counterbalanced order of presentation across trials.

Within each story type (physical or emotional), stories were presented in a random order. Physical and emotion stimuli were made as similar as possible to allow analysis of the impact of physical violations of expectation in contrast to incongruent emotion outcomes.

EEG protocol. Electrical Geodesics, Inc. 129-channel sensor nets (Tucker, 1993) were used and data was collected and recorded using NetAmps Series 300 amplifier (Electrical Geodesics, Inc.) and NetStation software (Electrical Geodesics, Inc.). Presentation was run using E-Prime 2.0 Software (Psychology Software Tools, Pittsburgh, PA) and ERP data was time-locked to the final image presentation using NetStation.

The test was carried out in the same location as Bennett's 2013 study, using the same equipment. To minimise distractions and reduce electrical interference, a dark, sound-attenuated room was used. Stories were shown on a computer screen positioned in front of the child, and a speaker behind the screen provided the audio track. One researcher was always present with the child throughout the task to read the on-screen instructions and prompt the child to remain still if required.

Before the task began, the child was shown their 'brainwaves' on NetStation and was encouraged to move to see what affect that had. The researcher explained that movement disturbed the recording and so they would need to sit very still while the task was taking place. They were told there would be a short break after every 12 stories when they could stretch. Impedances were checked using a 100kΩ threshold and digital filters were applied: Lowpass 30Hz, Highpass 0.3Hz and Notch 60Hz.

Instructions on the screen read "Please think about how the person in the story is feeling" at the start of the emotion story block, and read "Please think about what will happen next in the story" at the start of the physical story block. The researcher would read this out and check the child understood before proceeding. The final image in each story (where an ERP was recorded) was presented for

2000ms. There was no gap between presentation of images within a story, but between each story was a 500ms gap. After every 12 stories an instruction on-screen would read “Take a break!!!” and the researcher would suggest that the child stretched and then encourage them to continue sitting still for the next set of stories. After all 48 stories had been shown, a message reading “Well done!! You have seen all of the stories.” was shown, the net was removed and children had a refreshment break with their parents.

TEC (Pons & Harris, 2000 – see Appendix I). The TEC was chosen as a standard comparison measure of emotion understanding. It uses a picture book with simple cartoon scenarios to investigate nine elements of emotion understanding: recognition, external cause, desire, belief, reminder, regulation, hiding, mixed and morality. These are further categorised into developmental phases (external, mental and reflective) with each phase seen as a pre-requisite for the next. Each question is illustrated with a single cartoon image of a child with no facial features, and can be answered by pointing to one of the four possible cartoon facial expressions: happy, just alright and two of sad, scared or angry (see Figure 4 for sample item).

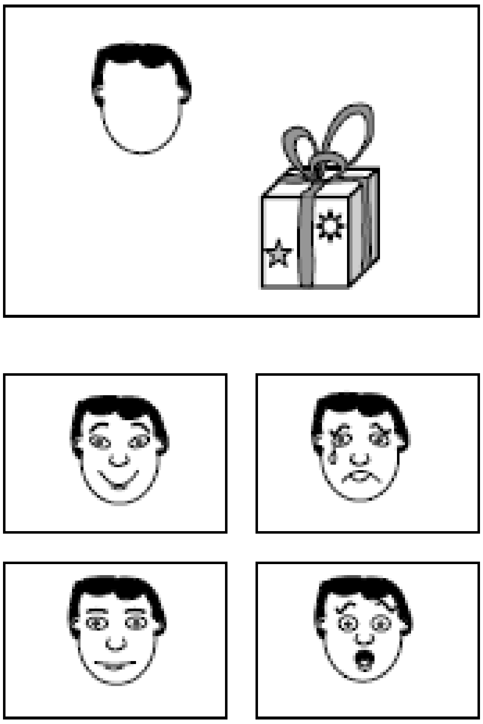


Figure 4. Example stimuli from the TEC. “This boy is getting a birthday present. How is this boy feeling? Is he happy, sad, just alright or scared?” Taken from Pons et al., 2003.

Versions of the book are available for boys and girls, but are identical apart from the gender and names of the characters. It was initially tested on a normative sample of 100 British children aged between 3 and 11 years (Pons et al., 2004), but has since been expanded to other populations (e.g.: Tenenbaum, Visscher, Pons, & Harris, 2004). It is scored as it is administered, with one point awarded for each of the nine components (total score ranges from zero to nine points). Components one and two (recognition and external cause) consist of five items each (one for each of the five emotions included) and a point is given for four or more correct answers, while components three to nine have only one test item each. The TEC has been shown to have good test-retest reliability (r =.84) over a three month interval (Pons, Harris, & Doudin, 2002).

Parent-report questionnaires. The parent was asked to complete the following questionnaire measures:

- Demographics form;

- Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997);
- Attachment Screening Assessment (ASA; Glaser, Hillman, Shmueli-Goetz, & Prior, 2013);
- Social Competence Scale (SCS; Conduct Problems Prevention Group, 1995); and
- Children's Behaviour Questionnaire – Short Form Version 1 (CBQ; Putnam & Rothbart, 2006).

Results from the ASA, SCS and CBQ are not reported here.

Demographics. A basic demographics sheet (see Appendix J) collected data regarding the child's date of birth, handedness and who made up their family. It also checked if any of the exclusion criteria for the EEG study were present.

SDQ (Goodman, 1997 – see Appendix K). The parent-report 4-17 year old version of the SDQ with impact supplement was used. It contains 25 statements about positive and negative psychological attributes which must be answered as 'Not True', 'Somewhat True' or 'Certainly True' (allocated a score of 0, 1 or 2). There are five scales: four problem scales (emotional, conduct, hyperactivity/inattention and peer) and a prosocial behaviour scale, each consisting of five items, with possible scores between zero and ten. A total difficulties score is the sum of the four problem scores with possible scores between 0 and 40. Items include "Many worries, often seems worried", "Often has temper tantrums or hot tempers" and "Has a least one good friend". The impact supplement asks whether the informant believes the child has a problem and if so to indicate the duration the problem has been present. An impact score ranging from zero to ten is given based on five questions relating to the level of distress caused and impact on different areas of functioning, each scored as: Not at all (0), Only a little (0), A medium amount (1) or A great deal (2).

The SDQ has demonstrated reasonable efficiency for detecting psychiatric disorders in community samples, with good sensitivity for externalising and depressive symptoms, although it struggled to identify certain anxiety symptoms (Goodman, Ford, Simmons, Gatward, & Meltzer, 2003). The total difficulties score has good reliability ($\alpha = .77$) for parental report of 5 to 6 year olds (Mieloo et al., 2012). The SDQ was recommended as a screen to identify children who may benefit from more detailed psychiatric assessment (Goodman et al., 2003) and is recommended by the UK CYP IAPT programme. Only results from the SDQ hyperactivity scale are reported here.

Ethics

Full ethical approval was gained from the UCL Research Ethics Committee (ID: 0384.096; Appendix L).

Analysis

EEG data analysis. The EEG data was analysed in MatLab (The MathWorks, Inc., 2007) using EEGLAB software (Delorme & Makeig, 2004). It was band-pass filtered, re-referenced and segmented into epochs from -200ms prior to stimulus presentation to 1500ms after stimulus presentation. The following filters were used: a 0.01Hz first order high-pass filter, a 50Hz notch filter to remove artifacts caused by electrical power lines and a Butterworth infinite impulse response filter (high-pass 0.1Hz, low-pass 30Hz). Up to 10% of channels were interpolated (for example if an electrode was not recording data or was showing interference).

Additional processing was performed using Fully Automated Statistical Thresholding for EEG artifact Reduction (FASTER; Nolan, Whelan, & Reilly, 2010). In addition to FASTER's independent component analysis (ICA), artifact detection software was also used in EEGLAB (moving window, saturation and voltage threshold artifact detection) to identify and remove epochs with high levels of artifacts. Finally, visual inspection of the data was used to identify significantly unacceptable levels of noise. If more than six trials (50%) in all conditions had acceptable quality following interpolation, then this participant's data was included in the analysis (84% of participants). Of the 36 participants whose data was accepted, 18 saw emotion stories first and 18 saw physical stories first. Of the trials in the 36 participants accepted for analysis, a mean of 7 channels were interpolated (5%, *SD* 4, range 0-13), a mean of 42 of the 48 trials were retained (87.5%, *SD* 4.7, range 30-48) and in total 1,528 trials were accepted.

For every accepted participant, average ERPs were created for each of the four conditions: emotion congruent, emotion incongruent, physical expected and physical unexpected. Electrodes and time windows used for each ERP component were taken from Bennett (2013), who based these on previous research findings (e.g.: Meinhardt et al., 2011) (see Table 3 in the results section, and Appendix M for a map of electrode locations). Grand average ERPs were then created for each of the four conditions, using data from all accepted participants. The total number of epochs analysed for each condition were: 381 emotion congruent, 388 emotion incongruent, 382 physical expected and 377 physical unexpected.

Statistical analysis. As a control, characteristics of children whose EEG data was accepted were compared against those whose EEG data was not. These groups were compared by age, gender, TEC score and SDQ hyperactivity score.

SPSS General Linear Model software (IBM Corp., 2012) was used to run 2 x 2 factorial repeated measures ANOVAs comparing physical vs emotion stories, and congruent/expected vs incongruent/unexpected stories for LPP, N400 and P3 components of the ERPs. These were also run for the N1 and P1 components, which relate to early visual processing, to control for differences in the visual properties of the emotion and physical stimuli. Post-hoc tests were then used to further investigate specific findings.

The overall TEC score was compared with the difference in amplitude in ERP components to see if these significantly correlated with higher levels of emotion understanding as measured by the TEC.

Results

First, results are presented comparing characteristics of children whose data was used with those whose data was not, in order to check for potential bias. Secondly, results from ERP component analysis are provided: initially demographic factors are considered, then analysis of components thought to be linked with emotion understanding, followed by those involved in visual processing. Finally, an analysis of associations between ERP components and TEC results is presented.

Demographics

The 36 children whose EEG data was accepted were compared with the 7 children whose EEG data was rejected. There were no significant differences in terms of age, gender, emotion understanding as measured by the TEC or hyperactivity as measured by the SDQ, and indeed their profile on these measures were numerically quite similar (see Table 1). Hyperactivity was investigated as movement during testing can result in artefacts preventing the recording of usable data, however it was not found to be a source of bias.

Table 1

Group Comparison: EEG Data Accepted or Rejected

Characteristic	**Used EEG group statistics (n = 36)**	**Unused EEG group statistics (n=7)**	**Test**	**Result**
Age (months)	*M* = 75.50 *SD* = 7.86 Range 64 – 89	*M* = 76.43 *SD* = 9.64 Range 62 – 87	Independent samples *t* test	*t*(41) = -.28, *p* = .784 n.s.
Gender	58% Female	57% Female	Pearson's chi-square (Fisher's exact test)	χ^2 (1) = 0.003, *p* = 1.000 n.s.
TEC score (max. score 9)	*M* = 6.14 *SD* = 1.62 Range 3 – 9	*M* = 6.57 *SD* = 1.72 Range 4 – 9	Independent samples *t* test	*t*(41) = -.64, *p* = .526 n.s.
SDQ hyperactivity score (max. score 10)	*M* = 3.00 *SD* = 2.62 Range 0 – 9	*M* = 4.57 *SD* = 3.15 Range 1 – 9	Mann-Whitney test (Kolmogorov-Smirnov: *D*(7) = .208, *p* = .200, *D*(36) = .194, *p* = .001**)	*U* = 88.00, *Z* = -1.27, *p* = .204 n.s.

Demographics and ERP Components

ERP components were analysed in terms of gender and age to determine if there were any significant effects of these demographic variables (see Table 2). No significant effect of age was found. Gender significantly affected the difference in LPP amplitude for physical conditions: with males showing significantly larger differences in amplitudes than females (male: *M* -5.37, *SD* 8.94, female: *M* -.08, *SD* 5.67). Gender also significantly affected the difference in LPP latency for emotion conditions: with males showing significantly larger differences in mid-point latency between congruent and incongruent emotion conditions than females (male: *M* 87.77, *SD* 169.80, female: *M* -38.92, *SD* 181.91).

Table 2

Effects of Gender and Age on ERP Components

Amplitude difference (unless specified)	**Gender (Independent *t* test)**	**Age (Pearson correlation)**
N400 for emotion conditions	$t(34) = -.638$, $p = .528$ n.s.	$r = -.144$, $p = .508$ n.s.
N400 for physical conditions	$t(34) = .015$, $p = .988$ n.s.	$r = .087$, $p = .614$ n.s.
LPP for emotion conditions	(Levene's test $F = 5.17$, $p = .029$** equal variances not assumed) $t(20.55) = .124$, $p = .902$ n.s.	$r = -.030$, $p = .863$ n.s.
LPP for physical conditions	$t(34) = -2.173$, $p = .037$**	$r = .002$, $p = .990$ n.s.
LPP latency difference for emotion conditions	$t(34) = 2.117$, $p = .042$**	$r = -.011$, $p = .951$ n.s.
LPP latency difference for physical conditions	$t(34) = -1.519$, $p = .138$ n.s.	$r = -.072$, $p = .679$ n.s.
P3 for emotion conditions	$t(34) = .030$, $p = .976$ n.s.	$r = -.122$, $p = .478$ n.s.
P3 for physical conditions	$t(34) = .175$, $p = .862$ n.s.	$r = .131$, $p = .445$ n.s.
P1 for emotion conditions	$t(34) = -.421$, $p = .676$ n.s.	$r = -.055$, $p = .750$ n.s.
P1 for physical conditions	$t(34) = 1.079$, $p = .288$ n.s.	$r = -.186$, $p = .277$ n.s.
N1 for emotion conditions	$t(34) = .320$, $p = .751$ n.s.	$r = -.102$, $p = .555$ n.s.
N1 for physical conditions	$t(34) = .320$, $p = .751$ n.s.	$r = .060$, $p = .729$ n.s.

ERP Analysis

The average amplitudes of the key components of interest are presented for descriptive purposes in Table 3. The average activity in the period 500ms before presentation of the stimuli provided a baseline.

Table 3

Mean Amplitudes for ERP Components

ERP component	Electrodes	Time period (ms)	Mean emotional congruent µV (SD)	Mean emotional incongruent µV (SD)	Mean physical expected µV (SD)	Mean physical unexpected µV (SD)
N400	Midline Central: Cz (129)	300-500	-0.35 (5.18)	-1.36 (3.59)	0.34 (3.99)	-0.38 (5.32)
LPP	Midline Frontal: Fz (11)	700-1495	0.80 (5.31)	3.79 (3.99)	1.74 (4.51)	4.03 (5.17)
P3	Midline Parietal: Pz (62)	300-600	5.25 (5.90)	4.98 (5.63)	7.28 (5.61)	7.40 (5.31)
P1	Right & Left Occipital: 65, 69, 70, 83, 89, 90	100-200	2.65 (4.28)	4.06 (4.40)	4.02 (3.62)	3.74 (3.78)
N1	Right & Left Occipital: 65, 69, 70, 83, 89, 90	200-300	1.31 (4.60)	2.25 (4.67)	4.72 (4.37)	4.21 (3.62)

N400. A factorial repeated measures 2 x 2 ANOVA demonstrated no significant effect of story type (physical or emotional: $F(1,35) = 1.462$, $p = .235$ n.s.), nor congruence (expected or unexpected: $F(1,35) = 26.858$, $p = .186$ n.s.) and no interaction effect ($F(1,35) = 0.715$, $p = .804$ n.s.).

The grand average graph (see Figure 5) appears to show the N400 component only clearly present in the emotional incongruent condition, and post-hoc tests were carried out to investigate this. Paired samples *t* tests showed no significant differences between emotional congruent and emotional incongruent conditions ($t(35) = 1.190$, $p = .242$ n.s.), nor between physical expected and physical unexpected conditions ($t(35) = .839$, $p = -.407$ n.s.). There were no significant effects of gender.

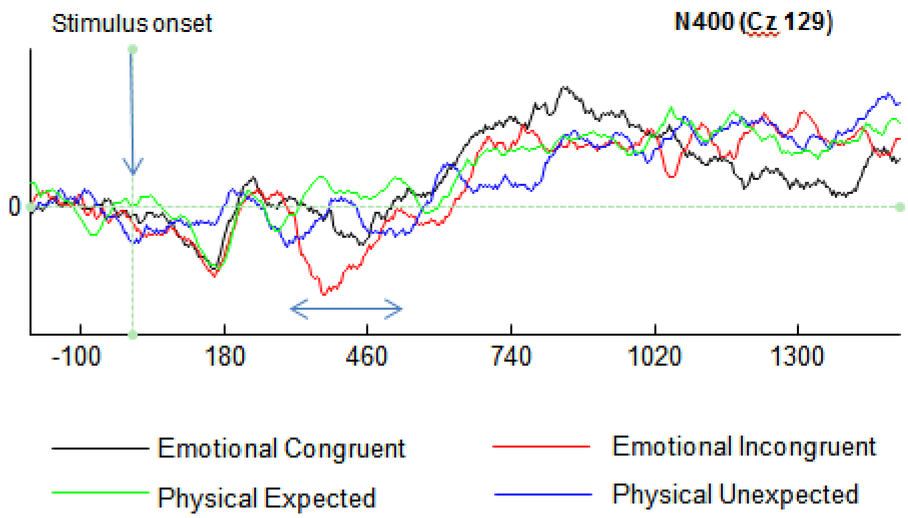


Figure 5. Grand average graph showing the N400 component.

LPP. A factorial repeated measures 2 x 2 ANOVA demonstrated no significant effect of type ($F(1,35) = 0.441$, $p = .511$ n.s.) and no interaction effect ($F(1,35) = 0.208$, $p = .651$, n.s.). However, a significant effect of congruence was found ($F(1,35) = 9.090$, $p = .005$**) with amplitudes higher for incongruent/unexpected conditions than for congruent/expected conditions. This replicates Bennett's (2013) study which reported a significant effect of congruence on the LPP ($F(1,32) = 27.818$, $p < .001$**, $d = .76$) and shows a larger effect size ($d = .96$).

The grand average graph (Figure 6) appears to show a later LPP for physical than emotional conditions. Post-hoc tests were used to investigate this by looking at the 50% fractional area latency (the duration at which point 50% of the area under the LPP curve is reached, see Table 4). A factorial repeated measures 2 x 2 ANOVA found no significant effect of congruence ($F(1,35) = 1.538$, $p = .223$ n.s.) and no interaction effect ($F(1,35) = 2.648$, $p = .113$ n.s.). However, as suggested by the graph a significant effect of type was found ($F(1,35) = 4.630$, $p = .038$**) with the LPP occurring later in physical conditions.

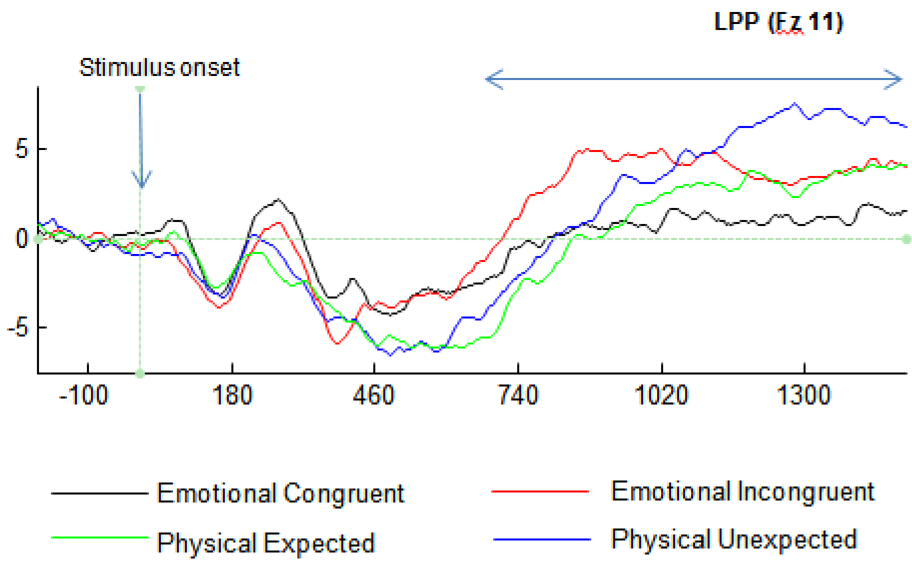


Figure 6. Grand average graph showing the LPP component.

Table 4

Mean Mid-point Latencies for the LPP

Mean emotional congruent µV (SD)	**Mean emotional incongruent µV (SD)**	**Mean physical expected µV (SD)**	**Mean physical unexpected µV (SD)**
1099.72 (97.55)	1085.85 (118.96)	1101.24 (111.47)	1157.02 (87.65)

Additionally, controlling for gender in this analysis resulted in a significant interaction effect (type * congruence: $F(1,34) = 4.467$, $p = .042$**). Emotion conditions showed later LPP midpoint latencies when congruent outcomes were presented, whilst physical conditions showed later LPP midpoint latencies when incongruent outcomes were presented. There is also a significant interaction effect involving gender (type * congruence * gender: $F(1,34) = 5.819$, $p = .021$**). Whilst the type * congruence interaction was present in male participants, no interaction was seen for female participants, where later LPP midpoint latencies were always found for incongruent outcomes (see Table 5). Pairwise comparisons of the estimated marginal means showed a significant difference in LPP midpoint latency between congruent and incongruent outcomes only for male participants in the physical condition ($F(34) = 7.582$, $p = .009$**).

Table 5

Mean Mid-point Latencies for the LPP by Gender

Gender	**Mean emotional congruent μV (SE)**	**Mean emotional incongruent μV (SE)**	**Mean physical expected μV (SE)**	**Mean physical unexpected μV (SE)**
Male	1143.193 (23.616)	1055.427 (30.405)	1086.580 (29.015)	1182.980 (22.209)
Female	1068.662 (19.960)	1107.586 (25.697)	1111.710 (24.522)	1138.476 (18.770)

P3. A factorial repeated measures 2 x 2 ANOVA demonstrated no significant effect of congruence (F(1,35) = .007, p = -.934 n.s.) and no interaction effect (F(1,35) = .060, p = .807, n.s.). However, an effect of type was found (F(1,35) = 6.832, p = .013**), with amplitudes higher for physical conditions than emotional conditions (see Figure 7).

Additionally, controlling for gender in this analysis resulted in a significant effect of gender (F(1,34) = 8.897, p = .005**), with lower amplitudes for female participants compared to male participants (female: *M* 4.851, *SEM* 9.015, male: *M* 8.155, *SEM* 10.667).

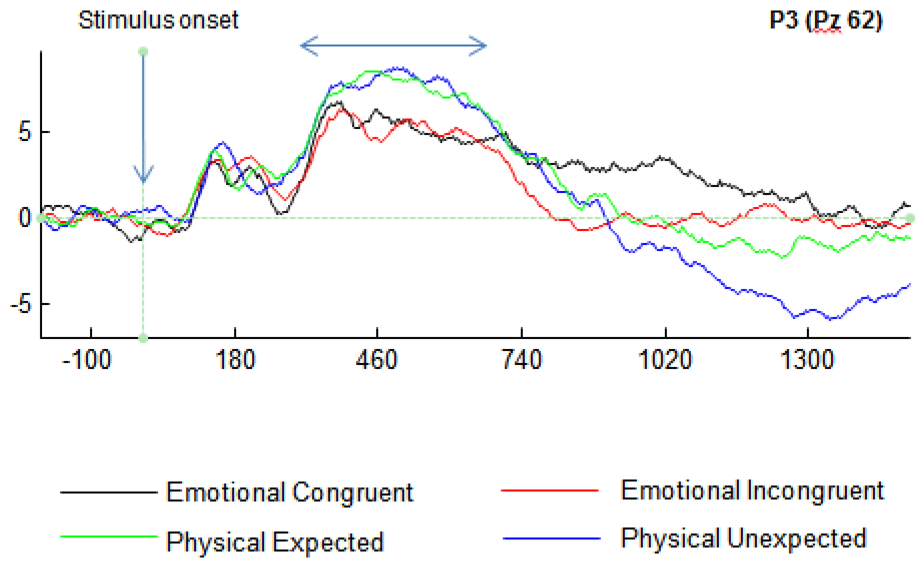


Figure 7. Grand average graph showing the P3 component.

Early visual processing components. P1 and N1 (see Figure 8) were analysed to control for differences in the visual properties of the emotion and physical stimuli.

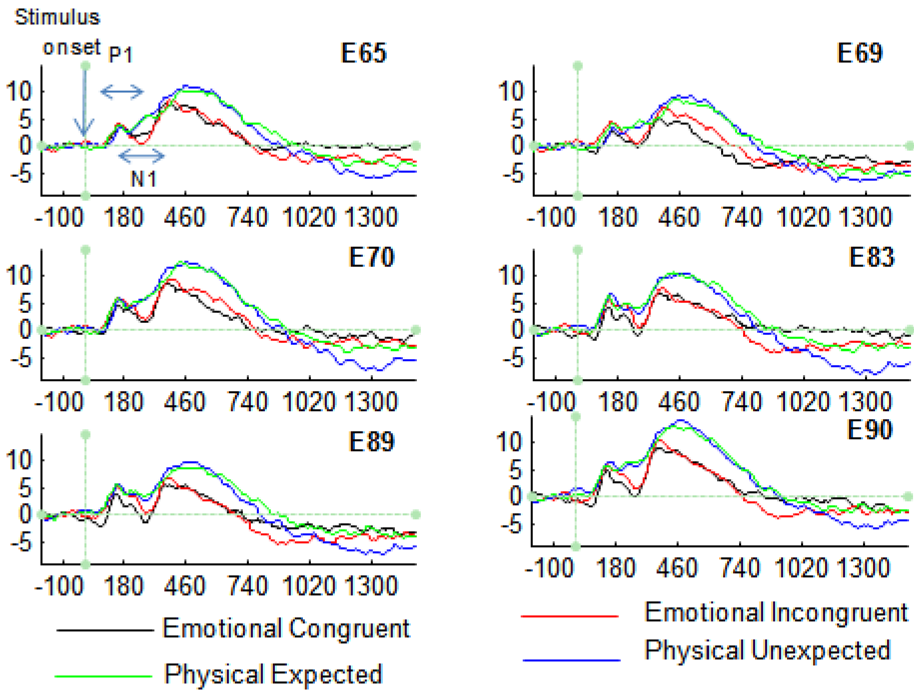


Figure 8. Grand average graphs showing the P1 and N1 components (across the six electrodes used).

P1. A factorial repeated measures 2 x 2 ANOVA demonstrated no significant effect of type ($F(1,35) = 1.066$, $p = .309$ n.s.), nor congruence ($F(1,35) = .664$, $p = .421$ n.s.) and no interaction effect ($F(1,35) = 1.917$, $p = .175$ n.s.). There were no significant effects of gender.

N1. A factorial repeated measures 2 x 2 ANOVA demonstrated no significant effect of congruence ($F(1,35) = .108$, $p = .744$ n.s.) and no interaction effect ($F(1,35) = 1.562$, $p = .220$ n.s.). However, a significant effect of type was demonstrated ($F(1,35) = 16.907$, $p < .001$**) with larger negativity for emotion conditions. There were no significant effects of gender.

Topographic maps. The topographic maps in Figure 9 show mean amplitude differences between conditions, illustrating the LPP timing discrepancy for activity between emotion and physical conditions, and the significant effect of congruency on midline frontal locations (LPP). Although activity is diffuse across the frontal area for the LPP, there is a possible indication of more lateralised activity in the right-frontal area for emotion conditions, and more lateralised activity in the left-frontal area for physical conditions.

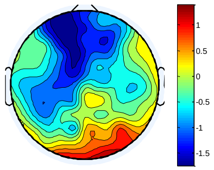
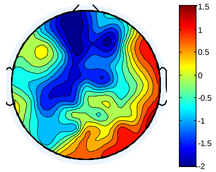
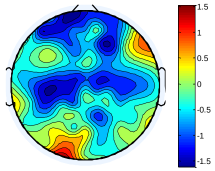
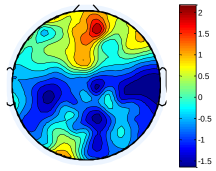
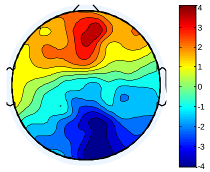
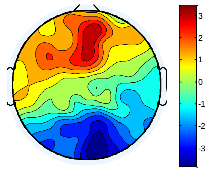
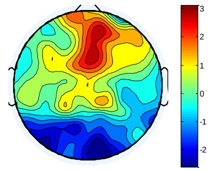
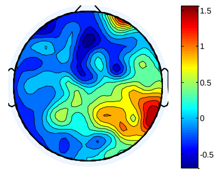
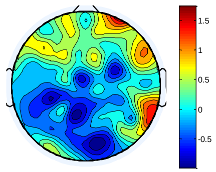
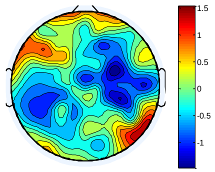
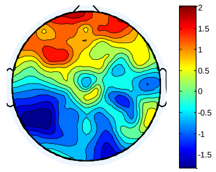
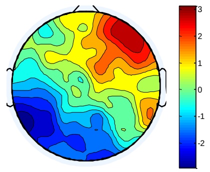
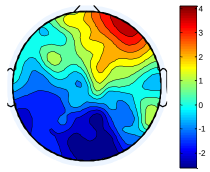
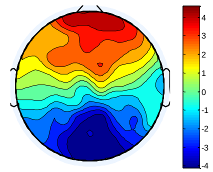
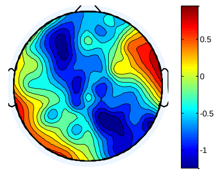
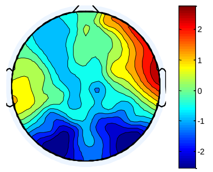
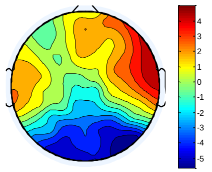
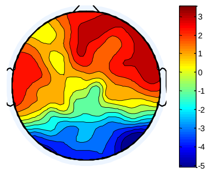
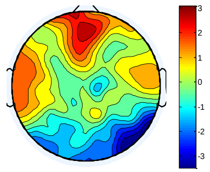
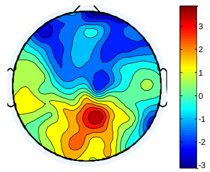
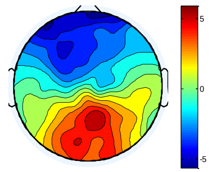
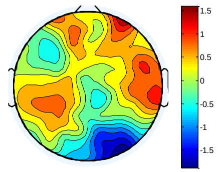
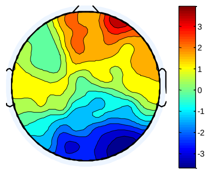
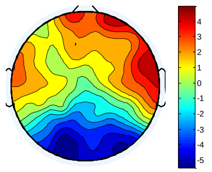
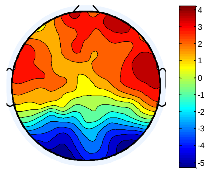
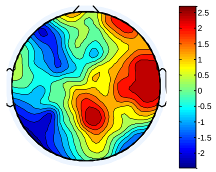
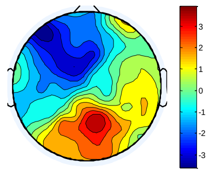
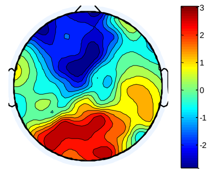
	0-200ms	200-400ms	400-600ms	600-800ms	800-1000ms	1000-1200ms	1200-1400ms
A) Congruence difference for emotion conditions (emotion incongruent mean amplitude minus emotion congruent mean amplitude)							
B) Congruence difference for physical conditions (physical unexpected mean amplitude minus physical expected mean amplitude)							
C) Type difference in incongruent conditions (emotion incongruent mean amplitude minus physical unexpected mean amplitude)							
D) Type difference in congruent conditions (emotion congruent mean amplitude minus physical expected mean amplitude)							
ERP components	P1 (right & left occipital)	N400 (midline central) N1 (right & left occipital)	P3 (midline parietal)	Early LPP (midline frontal)	Mid LPP (midline frontal)	Mid LPP (midline frontal)	Late LPP (midline frontal)
Description		Large differences (blue) in midline central amplitudes in A & B – showing smaller N400 for congruent than incongruent conditions, particularly for emotion (A). Large differences (blue) in right & left occipital amplitudes in C & D – showing smaller N1 for physical than emotion conditions.	Large differences (blue) in midline parietal amplitudes in C & D – showing the higher P3 for physical than emotion conditions.	Large differences (red) in midline frontal amplitudes in C & D – showing the larger early LPP for emotion conditions than physical conditions. Whilst frontal activity is diffuse, there is a possible indication of more activity in the right-frontal area.	Large difference (red) in midline frontal amplitudes in A – showing the larger LPP for incongruent emotion than congruent emotion conditions, Large difference (red) in midline frontal amplitudes in C – showing the larger mid-LPP for emotion incongruent than physical unexpected conditions.	Large differences (blue) in midline frontal amplitudes in C & D – showing larger later LPP for physical than emotion conditions, with a possible indication of more activity in the left-frontal area in D. Large differences (red) in midline frontal amplitudes in A – showing the larger LPP for incongruent than congruent emotion conditions.	Large differences (blue) in midline frontal amplitudes in C & D – showing larger later LPP for physical than emotion conditions, with a possible indication of more activity in the left-frontal area. Large differences (red) in midline frontal amplitudes in A & B – showing larger LPP for incongruent conditions.

Figure 9. Topographic maps showing mean amplitude differences between conditions across 200ms time periods.

TEC Analysis

The overall TEC score was compared with the ERP components to see if higher levels of emotion understanding as measured by the TEC, correlated significantly with different amplitudes in emotion conditions. No significant associations were found (see Table 6).

Table 6

Associations between TEC Score and ERP Components

Amplitude difference (unless specified)	**Result (Pearson correlation)**
N400 for emotion conditions	r = -.325, p = .053 n.s.
N400 for physical conditions	r = -.212, p = .215 n.s.
LPP for emotion conditions	r = -.117, p = .497 n.s.
LPP for physical conditions	r = -.182, p = .287 n.s.
LPP latency difference for emotion conditions	r = .255, p = .134 n.s.
LPP latency difference for physical conditions	r = -.060, p = .727 n.s.
P3 for emotion conditions	r = -.173, p = .312 n.s.
P3 for physical conditions	r = .209 p = .221 n.s.
P1 for emotion conditions	r = .229, p = .178 n.s.
P1 for physical conditions	r = .154, p = .370 n.s.
N1 for emotion conditions	r = .148, p = .388 n.s.
N1 for physical conditions	r = .165, p = .337 n.s.

An independent t test showed no significant association between TEC score and gender ($t(34) = .602$, p = .551 n.s.), but a Pearson correlation showed a significant association between TEC score and age (r = .422, p = .010**), with TEC score increasing with age.

Discussion

This study aimed to explore neural correlates of emotion understanding, specifically looking to replicate Bennett's (2013) finding of a late LPP for emotionally incongruent outcomes. Further, it aimed to compare the impact of congruence on emotional and physical stories, to investigate whether neural differences could be observed in the processing of incongruent outcomes between these two conditions. Finally, it aimed to compare a self-report measure of emotion understanding (the TEC) with the results of the EEG task.

Summary of Findings

There were no significant differences between the children whose data was used and those whose data was not, suggesting no systematic bias.

When correlations between demographic variables and ERP components were carried out, no significant effect of age was found. However, significant effects of gender were observed: affecting the difference in LPP amplitude between congruent and incongruent physical outcomes (males showing a larger difference in amplitude) and the difference in LPP latency between congruent and incongruent emotion outcomes (males showing larger differences in mid-point latency).

Of the ERP components thought to be linked with emotion understanding, no significant effect was found on the N400 component. A significant effect of congruence was found on LPP amplitude, with larger LPP for incongruent outcomes, replicating Bennett's finding (2013). A significant effect of type was found on LPP latency with physical conditions showing a later LPP compared to emotion conditions. A significant effect of type was also found on P3 amplitudes, with larger P3 components found in physical conditions.

LPP midpoint latency showed a significant interaction effect (type * congruence), but only for male participants. In physical conditions male participants had later LPP midpoint latencies for incongruent outcomes, but in emotion conditions they had later LPP midpoint latencies for congruent outcomes, whilst female participants always showed later LPP midpoint latencies for incongruent conditions. There was also a significant effect of gender on P3 amplitudes, with female participants showing lower mean amplitudes.

Of the early visual processing components, no significant effect was found on P1 amplitudes, but a significant effect of type was observed on N1 amplitudes: with larger N1 components for emotion conditions.

Comparing the TEC with ERP components produced no significant associations. TEC scores did not significantly correlate with gender, but significantly increased with age.

Review of Aims

Neural index replication. This study aimed to replicate Bennett's 2013 finding of a neural index of emotion understanding and achieved this, replicating the finding that LPP amplitude is significantly higher for incongruent emotion outcomes. A larger effect size (d = .96) was found in this study, strengthening the initial finding.

Neural correlate. Through the introduction of the physical stories, the study aimed to clarify if the greater LPP for incongruent emotion conditions was a specific neural correlate of emotion understanding or an index of emotion understanding which was also present with other unexpected outcomes. Greater LPP amplitudes were found for both emotionally incongruent and physically unexpected conditions. The lack of a significant interaction between congruence and story type for LPP amplitudes demonstrates that the greater LPP is not a specific neural correlate of emotion understanding, and is also observed when non-emotion unexpected outcomes are presented.

As in Bennett's initial study (2013), the congruent and incongruent scenes can be assumed to require approximately equal levels of general processing and so the LPP effect can be attributed to the additional cognitive demand of making sense of the incongruent outcomes. In this study, contrary to previous research, larger LPP responses were not specific to emotional images – both emotional and physical incongruent outcomes elicited larger LPP responses. It seems that the larger LPP was related to cognitive processing of the difference between expected and observed stimuli, rather than the image's emotional content.

LPP latency was found to be significantly different for physical and emotion conditions, with the LPP occurring earlier for emotion conditions. This finding may be due to the differences in the emotion and physical stimuli. In the physical ERP eliciting image the change may happen in different areas of the image (rather than only in the face outline provided in emotion outcomes); the change therefore may not occur in the area attention is initially directed at. Also, physical ERP eliciting images complete the story, providing one of a wide range of possible outcomes (rather than only happy or sad expressions as in emotion outcomes) and additional processing time may be required to take in the extra information provided in physical outcomes.

Bennett (2013) found no significant difference in N400 components and the N400 was predicted to occur either solely in physically unexpected conditions, or also in emotional incongruent conditions. In fact the N400 was not significantly different between any of the conditions. The N400 indicates a violation of semantic expectation and so one possible explanation would be that the incongruent conditions did not surprise the participants (did not violate their expectations). However, this is not supported by unprompted comments made by participants expressing surprise at the outcome of emotion incongruent and physical unexpected stories.

Studies investigating the impact of congruence have reported significant effects on LPP but not on N400 (pairs of emotional stimuli; Herring et al., 2011), or significant effects on both (incongruent behaviour by a character in a story; Baetens et al., 2011). This has been understood as demonstrating that N400 increases as additional effort is required to make sense of the inconsistent information, whilst LPP increases as additional attention is paid to evaluatively incongruent information (Baetens et al., 2011). Whilst emotional outcomes are not entirely predictable (and children are likely to have observed others responding differently to similar situations), the physical unexpected outcomes are not situations they would have observed – suggesting that the inconsistent information would need to be processed. Also, the presentation of information in this task was in story format (rather than stimuli pairs), suggesting that additional effort would have been needed to understand the inconsistent information, resulting in a significant N400.

One possible explanation is that the nature of the EEG task reduced the amplitude of the N400 to a level where no significant difference could be seen. Studies have shown that the N400 response is most pronounced for semantically incongruent outcomes when participants have to actively respond, and diminishes for passive tasks where the instruction is to listen and watch (Erlbeck, Kübler, Kotchoubey, & Veser, 2014). Erlbeck et al. (2014) found that although the N400 was strongly attenuated in passive conditions, it was still present. In this study children were instructed to watch and think about the story, but not to actively respond. It may be that the passive nature of the task diminished the N400 response to a level where no significant differences could be observed between congruent and incongruent conditions.

ERP and TEC. The study had aimed to correlate ERP components with self-report data on emotion understanding, however no significant association was found between TEC score and ERP components. Two possible explanations for this finding are the impact of ceiling effects of the EEG task, or the impact of language ability on the TEC.

Although both tests investigate emotion understanding, the EEG task looked specifically at affective perspective taking, whereas the TEC assessed nine different components of emotion understanding including of mixed and hidden emotions. It may be that while the TEC investigated more advanced emotion understanding skills, all the children achieved a ‘pass’ on the EEG task and so no relationship was seen. It would be interesting to repeat the task with younger children, who may not all ‘pass’ the EEG task and see if a relationship between ERP response and TEC score is then found.

An alternative explanation would be that language demands required to complete the TEC are higher than those required for the EEG task. Language ability has been shown to explain a significant amount of the variance in self-report emotion understanding tasks: in a comparison using the TEC, language explained 27% of the variance in emotion understanding (Pons et al., 2003). It may be that language ability limits the children's performance on these tasks and therefore underestimates their emotion understanding. As a brain-based measure, the EEG task reduces the reliance on language and may therefore potentially offer a more accurate measure of emotion understanding. The addition of a language ability measure would allow relationships between language level and emotion understanding to be investigated further.

The TEC was significantly correlated with age, whilst ERPs showed no correlation with age. As outlined above, the lack of correlation between ERPs and age may be due to ceiling effects of the EEG task. The correlation between TEC scores and age was expected, as age has been shown to explain a significant portion of variance in emotion understanding tasks (20%; Pons et al., 2003), and the TEC is designed to test components of the three developmental phases of emotion understanding (Pons et al., 2004).

Additional Findings

Several additional significant findings were shown. A significant effect of type was found on P3 amplitude, with larger P3 for physical conditions. The P3 reflects attention updating existing contextual models in working memory with new information. Physical stimuli show much greater variation than emotion stimuli (which always show only the addition of a positive or negative emotion expression). In the physical stimuli the outcome can occur in different parts of the picture and although certain themes are repeated (e.g.: items bouncing or breaking) the context and image location of this occurrence varies in each story. It may be that the larger change, and the larger number of possible outcomes explains why additional attention was required to update working memory for these stories in comparison to the emotion stories. It is a limitation of the design that in emotion conditions the story effectively finishes before presentation of the ERP eliciting stimuli which just reveals one of two emotions, whereas in physical conditions the story is completed in the ERP eliciting stimuli which is different to the previous image in one of many different ways.

A significant difference was also found in the early visual processing component N1, with emotion conditions showing a larger negativity than physical conditions. Larger N1 amplitudes have been found in response to stimuli in attended locations (Anllo-Vento & Hillyard, 1996). Emotion outcomes always appear within the face outline shown on the previous image, so attention can be focused on this area, whilst physical outcomes can be shown in different parts of the image and are not always as clearly cued as the emotion outcomes. This may have resulted in emotion outcomes (but not physical outcomes) being presented in the attended visual field and therefore generating larger N1 responses.

However, the P1 component also increases for attended areas (Anllo-Vento & Hillyard, 1996) and was not found to be significantly different between conditions. This suggests that instead of a function of attention, it is the emotional content of emotion stimuli which are responsible for the larger N1. Foti, Hajcak, & Dien (2009) found that positive or negatively valenced images (including happy and sad faces) elicited larger N1 responses than neutral images. The neutral physical stimuli may therefore have resulted in smaller N1 responses than the happy and sad faces in the emotion stimuli.

Whilst further analysis would be required to investigate any laterality effects of story type on the LPP, topographic maps suggest that emotion conditions may show a right lateralised frontal LPP, whilst physical conditions may show a left lateralised frontal LPP. A laterality effect on the frontal LPP has previously been reported, but in respect to valence: greater left hemisphere activity in response to positive stimuli and greater right hemisphere activity in response to negative stimuli (Cunningham, Espinet, DeYoung, & Zelazo, 2005). It is possible that emotion processing may be lateralised on the right, although a meta-analysis found no support for the theory of right-hemisphere dominance in emotion processing (Wager, Phan, Liberzon, & Taylor, 2003). As children tend to show more diffuse patterns of activation than adults (Casey, Giedd, & Thomas, 2000), it would be interesting to investigate whether the EEG task results in any significant laterality effects in adults.

Several significant effects of gender were found: males showed larger LPP amplitude differences between congruent and incongruent physical outcomes, and larger differences in LPP midpoint latency between congruent and incongruent emotion outcomes. A significant effect of gender was also found on P3 amplitudes, with male participants showing higher mean amplitudes than female participants. Larger P3 amplitudes have been reported for men during spatial-attention tasks (Vaquero, 2004) however in other visual tasks including object recognition women have demonstrated larger P3 amplitudes (Steffensen et al., 2008), suggesting that potentially this gender effect may be related to attention. A significant interaction between story type and congruence was found for LPP latency, but only for male participants. Incongruent outcomes always had later LPP midpoint latencies than congruent outcomes, except for male participants in emotion conditions where congruent outcomes showed a later LPP midpoint latency. This study is not able to provide explanations for these unexpected findings, but these may be areas to investigate in future research.

Limitations

This was a follow-up and extension of an initial test of a novel EEG paradigm. Whilst replicating and extending the findings, the study has several limitations. These will be discussed as they relate to the initial premise of the EEG task, to the introduction of the physical conditions and finally to the use of the TEC.

As outlined above, the emotion conditions of the EEG task may demonstrate ceiling effects in this age group. Whilst testing more than emotion recognition, they test basic affective perspective taking and more variation in effect may be seen with a younger sample, or with the inclusion of more complex emotion understanding concepts. The passive nature of the task may have affected the identification of any differences in N400 components. An active task (requiring a key press for example) would allow investigation into whether the impact of task nature was responsible for the lack of difference in N400 amplitudes between conditions. By asking for a response it would also be possible to see if participants found the incongruent outcomes unexpected, or if the lack of an N400 response was instead due to a lack of violation of expectation. However, the additional information gained would need to be weighed against the likely increase in movement artefacts as a result of instructing young children to respond.

Additionally, there are several generic limitations of EEG: it is only able to accurately measure activity in the superficial layers of the cortex, the signal-to-noise ratio is poor and the low spatial resolution makes it difficult to pinpoint the location responsible for particular ERP responses. There is also an element of interpretation involved in the choice of latency periods and electrodes used for ERP components.

The addition of the physical conditions introduced some further limitations. In EEG studies it is advisable to vary experimental condition within rather than between trial blocks (Luck, 2005). This was considered, but it was determined that the different instructions (to think about how the character was feeling, or what would happen next) would be too confusing if the two conditions were randomised. Presentation order was counterbalanced across trials to try to minimise the impact of grouping by type.

Although efforts were made to match physical stimuli to the existing emotion stimuli, there were differences in the stimuli. These differences ranged from the style of drawing and brightness of colour, to the type and location of the difference in the ERP eliciting image. Physical stimuli featured one of many varied outcomes which could occur at locations which were not predefined, whereas emotion stimuli featured only a happy or sad face, occurring within the face outline presented in the immediately preceding image. The specified location for attention in the emotion condition may have affected the early processing ERP components – although the effect on N1 but not P1 suggests that attention may not have contributed greatly to the result. As the story was completed in the final image for physical conditions there was more information for participants to take in from the ERP eliciting stimuli in these conditions which may have affected the P3 component.

To minimise these limitations, the same story images could be used to create both emotion and physical stimuli, counterbalanced so that half the participants see a set of stimuli with an emotion story, whilst the other half see the same stimuli with a physical story. This would remove any impact of picture style, colour or brightness. A cross could be used to indicate where the change would appear in the ERP eliciting image to reduce any bias the face outline in emotion conditions has in directing attention to the location of the change. Additionally, limiting physical outcomes to one of two options (for example, break or bounce) would reduce differences between the two conditions.

Finally there are limitations related to the use of the TEC. The TEC tests nine different components of emotion comprehension, including more advanced skills than those tested by the EEG task. It may be more helpful to create a self-report version of the EEG task as an exact comparison measurement of emotion understanding. This would also allow confirmation that the incongruent outcomes used were indeed unexpected. Also, a large portion of the variance in TEC scores has been explained by language ability which was not measured in this study. If repeated, then the use of a measure of verbal ability would be helpful to investigate if brain-based measures of emotion understanding remove limitations of language ability which may affect self-report measures.

Implications

Given this was only the second study into this paradigm, at this point most of the implications of this study are for further research to refine and develop the brain-based measure of emotion understanding. Further research addressing the limitations outlined above is recommended, including extending the study to younger children and testing against a self-report version of the EEG task. Additionally, the use of fMRI could allow more accurate identification of the brain areas involved in the ERP responses identified by the EEG.

However, there are also potential clinical implications to investigate differences in the neural basis of emotion understanding in neurodevelopmental disorders. Once a baseline of neurotypical children's emotion understanding can be established using the EEG paradigm, the task could then be extended to other populations. It would be interesting to use the EEG task with populations with ASD to investigate any neural developmental differences in emotion processing and understanding.

It may be that the neural basis of emotion understanding develops later in children with ASD, resulting in delayed emotion recognition. Alternatively differences in neural networks may underpin emotion understanding difficulties in ASD. It would be interesting to investigate if neural differences in affective perspective taking are observed in both children and adults with ASD, or if the neural networks identified in neurotypical populations are used but develop later.

The EEG task could be used as a screening tool, to identify children with poor affective perspective taking skills who might benefit from interventions to increase social competence. The EEG task could also be used as an outcome measure to track and assess the effectiveness of these interventions: monitoring improvement and investigating whether neural changes took place.

Additionally, extending the EEG task to populations with language difficulties, would allow investigation of whether brain-based measures show higher levels of affective perspective taking in comparison to traditional self-report measures. If it did, this would support the idea that there is a limiting effect of language on self-report measures, and that brain-based measures provide more accurate assessment of emotion understanding.

In conclusion, there is strong evidence for a neural index of emotion understanding which can be used to assess affective perspective taking ability. As a brain-based measure it may also allow more accurate assessment of emotion understanding skills, with less reliance on language than traditional self-report measures, and could be extended to investigate neural differences in affective perspective taking in ASD populations.

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Part 3: Critical Appraisal

The Role of Science in EEG and Clinical Psychology

Introduction

During this research I began to question the scientific nature of electroencephalogram (EEG) analysis, leading me to consider the importance of psychology being seen to be ‘scientific’, and to explore what biological markers can add to self-report data. This critical appraisal will discuss each of these in turn: considering the limitations and role of interpretation in EEG and the use of complementary biological methods to improve spatial resolution, the position of psychology as scientific and questions of objectivity and ecological validity, and the value added through the use of biological markers.

The Science of EEG

I come from a science background, studying a mix of biological and social sciences before specialising in psychology. My initial impression of EEG was that it was a pure scientific form of investigation: identifying biological markers and proving theories using factual, observable findings. The technicality of the EEG and the precision of the method supported this impression and certainly the children who participated were excited to be taking part in a ‘proper science’ experiment. This fit well with the profession’s aim for psychologists to be scientist practitioners using evidence-based treatments, as well as with UCL’s clinical psychology doctorate’s aim to train ‘scientifically-oriented’ clinicians (UCL, 2015).

However, as I learnt more about the data processing and analysis of EEG, I increasingly found that judgement and interpretation were required to translate the recorded data into results. Raw EEG data is subject to various filters, before interpolation takes place. Filters are widely used in EEG studies to increase signal-to-noise ratio, however research has shown that they can distort the signal, resulting in systematic bias and filtering artefacts which may affect interpretation (Acunzo, MacKenzie, & van Rossum, 2012). It is a trade-off situation: the gain in signal-to-noise ratio against the introduction of possible filter artefacts.

Interpolation allows for an approximate value to be calculated and allocated to channels which were not recording activity (for example, as a result of a broken wire in the EEG electrode net). Interpolation uses scalp locations close to the missing channel which are assumed to have similar voltage values. Interpolation can also be used on channels which appear to show high levels of artefacts or interference. This is a process that is done on the basis of the researcher’s judgement – another trade-off: balancing the desire for ‘good’ data with as many accepted epochs as possible, against the fact that each interpolation is ‘creating’ data which is only an approximation of what should have been recorded.

Following interpolation, independent component analysis (ICA) is used. This looks for stereotyped artefacts such as those caused by blinks and applies a correction: another layer of estimation of the actual electrical activity. Re-referencing is performed using a reference channel, however even with dense-array 129-channel nets the surface potential is not fully sampled across the whole head and so re-referencing has been shown to introduce a further bias: the polar average reference effect (Junghöfer, Elbert, Tucker, & Braun, 1999).

Once the data has been processed in this way, through trade-offs potentially resulting in the introduction of bias, artefacts and approximate estimations of data, it can then be analysed. EEG analysis also includes strong elements of interpretation. The aim of event related potential (ERP) studies is usually to investigate how one or more specific ERP components are affected by the study variables. However, there is no way to directly access individual ERP components and so inferences must be made on the basis of the ERP waveforms (Luck, 2005). The ERP waveform is made up of many different components and measurement of a single component can be distorted by others as they typically overlap in both time and space. This ‘component overlap’ difficulty has not been adequately addressed through analysis techniques, although some components can be identified by their specific scalp distribution (Woodman, 2010).

To analyse a specific ERP component, one or more electrodes must be chosen to be investigated in a given time window. These are often based on previous research studies, but do show substantial variation. For example, a quick search of recent studies investigating the LPP component shows that a range of time windows have been used: 450-550ms (Schmitz, Scheel, Rigon, Gross, & Blechert, 2012), 500-1000ms (González-Garrido, López-Franco, Gómez-Velázquez, Ramos-Loyo, & Sequeria, 2015) and 400-2000ms (Hajcak & Olvet, 2008). Not only do the start and end point of these time windows vary, but the duration studied ranges from 100ms up to 1600ms. The time window chosen can affect the interpretations that are made and expert advice is that they should be similar to earlier research into the specific component, and should cover the whole of the component across every participant's waveform (Woodman, 2010). Whilst it is difficult to choose a time window similar to earlier research when this ranges so widely, broader windows are recommended to reduce the selection bias that is found when a narrow window focused on the peak amplitude is chosen (Woodman, 2010).

The analysis of the 'cleaned' data involves judgements regarding which individual ERP components can be identified and separated from their neighbours, and decisions about the locations and time windows which will be used to investigate them. In addition, further decisions about whether amplitude or latency are analysed and within that whether peak, average or fractional measurements are reported. Further, inferences are then made, on the basis of differences in ERP components, that qualitatively different underlying cognitive processes are represented: assuming an exact mapping of neural activity and functional processes, not always supported by research (Otten & Rugg, 2005). My impression of EEG had changed from considering it to be a pure science to a more subjective and interpretative methodology.

However, interpretation is needed in all sciences. Even Nature, the 'international weekly journal of science', states that: "scientific judgement itself is value-laden, and that bias and context are integral to how data are collected and interpreted" (Sutherland, Spiegelhalter, & Burgman, 2013, p. 335). This is equally true for hard science, where the same data can be reinterpreted to call into question earlier conclusions. Discover, a magazine described as 'science for the curious', wrote about this in relation to physicists' reanalysis of data on nanoparticles, explaining that data itself is not science: it has to be interpreted and these interpretations can be incorrect (Neuroskeptic, 2014). This follows Nietzsche's philosophy of science: that even in physics there are no facts, only interpretations (Babich, 1994). The need for interpretation does not make EEG data less scientific, but awareness of the potential limitations and sources of bias are important to consider when drawing conclusions from the data.

Alternative to EEG

An alternative to EEG for investigating brain responses is functional magnetic resonance imaging (fMRI). This allows visualisation of blood flow to different areas of the brain to infer which areas are active in specific tasks from their increased oxygen uptake. EEG directly records electrical activity and therefore offers much more accurate temporal resolution: detecting changes within 1ms, compared to changes within seconds in fMRI.

However, whereas EEG is only accurately able to measure activity in the superficial layers of the cortex, fMRI can be used to measure activity across the central nervous system. FMRI also allows more accurate spatial resolution (within approximately 1mm) producing detailed images of brain tissue, whereas the source of scalp recorded activity cannot be identified with EEG. It is possible to use fMRI together with EEG to allow both temporally and spatially accurate measurement. For example, event-related fMRI data was combined with EEG data to investigate the neural generators of a particular ERP component involved in target detection (Menon, Ford, Lim, Glover, & Pfefferbaum, 1997).

Repeating this study but adding fMRI would allow more accurate identification of brain areas involved in emotion understanding. fMRI can now be obtained concurrently with EEG using simultaneous imaging for tomographic electrophysiology (SITE). It does present new challenges – the MRI causes artefacts in EEG data and EEG acquisition equipment interferes with fMRI image acquisition. These can be reduced through filtering, or using fMRI only to take snapshots at intervals, allowing EEG data to be recorded in between slice acquisition (for example: Goldman, Stern, Engle, & Cohen, 2002). Also, as fMRI and EEG data have different time courses, the delay in haemodynamic response measured by fMRI has to be considered in analysis. Although simultaneous fMRI and EEG has been used with children (Moeller et al., 2008), it is likely to be more anxiety provoking for them than EEG alone. It also requires additional specialist equipment and is very expensive to run.

The Science of Psychology

My changing perception of the science of EEG led me to reflect on whether psychology aims to be a science, and whether it should. The British Psychological Society states in its ‘introduction to psychology’ that: “Psychology is a science and psychologists study human behaviour by observing, measuring and testing, then arriving at conclusions that are rooted in sound scientific methodology” (BPS, 2015). The American Psychological Association also defines psychology as: “grounded in science… [applying] the discipline’s scientific knowledge to help people” (APA, 2015). It seems clear that psychology aims to be considered scientific, but why?

Psychology has been positioned as a ‘hub science’, directly tied to medicine, neurology and social sciences (Boyack, Klavans, & Börner, 2005). Where ‘hard’ natural sciences are associated with rigorous method, objective observers and precise measures, ‘soft’ social sciences have at times been considered less legitimate or even unscientific. Perhaps it is this position, on the cusp between the soft and hard sciences that leads to an apparent desire for psychology to position itself more closely with the hard sciences. When disagreements over evidence for psychological interventions considers only ‘scientific’ or a disparaging alternative of ‘pseudoscientific’ (for example Herbert et al., 2000), it becomes clear that ‘hard’ science is highly valued in psychology. It has been argued that the use of biological measures, such as EEG, aim to: “make psychologists look more like “hard” scientists to other “hard” scientists” (Kraus, 2013).

However, it isn’t only the scientists that psychology is trying to convince. Arguments about the validity of psychology as a science have been linked to funding issues and play out in the popular media. Whilst categorising psychology as a soft science, Wilson (2012) wrote in the Los Angeles Times to defend psychology against claims that hypotheses in social sciences are usually unfalsifiable – a key tenet of Popper’s empirical scientific method. A response was printed the following day, in which a microbiologist argued psychology isn’t science as it doesn’t meet the criteria of scientific rigor – and that even when psychological research is more scientific it is dangerously trying to redefine science away from “the empirical analysis of the natural world…[so] anything can qualify as science” (Berezow, 2012). Position pieces in Scientific American followed this, with arguments that measurement in all science is complicated and psychology is no different (Tannenbaum, 2013) and that Berezow’s objections regarding definitions and quantifiability can equally be applied to concepts in hard sciences such as chemistry (Jogalekar, 2013).

Impression management and popular opinion are important if decisions about clinical interventions are affected, either at the individual or commissioning level. The positioning of clinical psychology as a science has been central to the identification and ‘marketing’ of ‘evidence-based’ interventions. Shedler (2013) has argued that currently there is no scientific basis that predominantly manualised, evidence-based interventions are more effective than ‘real-world therapy’, and that the term ‘evidence-based’ is used as a marketing tool, commonly recommended in the press. Shedler’s arguments include: the use of comparisons against no treatment or against treatments without any psychological input, and publication bias (shown to considerably overestimate the effects of psychological interventions including CBT; Cuijpers, Smit, Bohlmeijer, Hollon, & Andersson, 2010). Shedler also cites the American Psychological Association’s conclusion that variability in treatment outcomes reflects differences in patient and clinician factors more than type of psychotherapy (APA, 2012).

Part of the drive for research into specific manualised treatments may be that they can be tested more scientifically – they are standardised and more easily replicable. Comparisons with non-manualised psychological treatments are less standardised and replicable and so instead research has used wait-list control or medication as alternative treatments. NICE guidelines for psychological management of conditions interpret evidence in the same way as for medication, surgery or medical technology – with the ‘gold standard’ of randomised controlled trials being given the most weight. In this context, taking a ‘scientific’ standpoint produces evidence allowing interventions to become recommended. As the evidence base is affected by, and in turn affects the funding available for specific treatments, it is crucial for psychological research to be seen as scientific.

Objectivity and Ecological Validity

As psychology is the study of human mind and behaviour by humans, a position of objectivity can be difficult to assert. Psychologists have questioned the objectivity of science: Mitroff (1972) asserted that objectivity in science is a result of discussions and debates between scientists with different biases, and that instead of working to eliminate bias it should be assessed and differences of opinion encouraged to facilitate self-reflexivity. However, one use of biological markers, such as EEG, in psychological research may be to show that the research is ‘real science', grounded in objective, observable, biological findings. The use of objective technology to record direct responses from a subject's brain gives a stronger basis for asserting objectivity – although the layers of judgement and interpretation then required leave space for this to be questioned further. EEG is used in medical research, for example into the assessment of coma patient prognosis (Husain, 2006) and its use in psychology makes research appear more similar to medical research.

However, although it may offer more objectivity, a drawback of EEG is the lack of ecological validity. Because of the technical requirements of the EEG, participants have to remain sitting very still to reduce movement artefacts, in a quiet, dark room with no additional electrical equipment which may cause interference. In this artificial setting, they are also asked to keep their face still, so normal facial expressions related to emotions are suppressed, which may impact on cognitive emotion processing. However, this is part of a trade-off: the quiet dark room makes it much easier to control for distractions, and is easier to standardise and replicate. A reduction in ecological validity is common as tasks become more highly controlled, or 'scientific'.

As EEG tasks require multiple trials to create average ERPs for analysis, tasks have to be repeated. This may impact on the results in different ways: participants may stop paying attention (which is difficult to assess in passive tasks, even with researchers checking that the participant is looking at the screen), they may start to expect unexpected conditions or start looking for patterns in the stimulus presentation (one child, whose data did not meet the criteria to be used, stated that he had "figured it out" and that there was a pattern of happy and unhappy faces). The standardised stimuli to reduce bias may have meant that stimuli were not culturally appropriate for each participant – for example showing boys and girls playing together unsupervised where this may not be permitted within certain religious or cultural contexts.

Value Added by Biological Markers

Taking a biopsychosocial perspective, psychological functioning is understood as being a combination of biological, psychological and social elements. Biological markers therefore, are not only used to increase perceived objectivity, but to add information from a different perspective that can help to increase understanding. The use of different forms of measurement provides distinct information. EEG allows an understanding of the chronology of different mental processes as they take place in a very short period of time after stimulus presentation, processes that are inaccessible to introspection and cannot be explored through self-report. However, self-report can give a description of the stream of consciousness experienced when presented with the same stimuli. Together a richer understanding can be developed.

By using EEG measures alongside traditional self-report measures, potential sources of bias can be evaluated. For example, the impact of language ability on self-report measures of emotion understanding can be explored further by comparing results from self-report and EEG measures and looking for a specific correlation of language ability with self-report. Biological markers including EEG can also be used in psychology for accurate assessment when deception or social desirability bias may affect self-report.

EEG measures can be used to assess populations where self-report is not possible: for example by studying early emotion recognition in pre-verbal infants to assess normal developmental timelines. Once normal patterns of brain activity for a specific task have been established then research can look to see how that activity differs in disorders, for example whether patterns of neural activity in emotion understanding tasks differ in populations with ASD. This can allow the identification of neurological markers to identify patterns of atypical development. EEG is already used in medicine to diagnose conditions such as epilepsy and narcolepsy; perhaps in the future this will be extended to diagnosis of neurodevelopmental disorders.

One concern I had for this study, using the scientific experimental method of EEG, was that perhaps it would be too theoretical, without clinical utility. Whilst the majority of recommendations are for future research, I think that the study has also made progress towards EEG tests to gain understanding of different neural pathways in ASD which may allow diagnosis of neurodevelopmental disorders, and to track the development of emotion understanding from infancy which may in turn allow identification of at risk groups for early intervention.

Conclusions

Overall this study has prompted me to question what constitutes science, the role that science plays both in the undertaking and presentation of psychology and the impact this can have on the clinical treatments that are available and recommended. I believe that discussion about the requirements for something to be called 'science' is important, not only for psychology, but for 'hard science' research too, where positions of empirical objectivity may limit reflection and acknowledgement of alternative possibilities. Awareness of limitations and discussions with those who disagree allows reflection and consideration of different possible interpretations of results.

Combining results obtained using different methods (either different biological methods such as concurrent fMRI and EEG, or mixed methods such as EEG and self-report), can strengthen findings or raise further questions and so is a useful strategy for increasing understanding. If different interpretations are available, an important consideration may be their utility. Perhaps the aim should be to focus on using data to produce interpretations that are useful at the present time, rather than to find an objective and unquestionable truth.

Whilst I appreciate the reasons for psychology to be 'scientific', I think it is important not to lose sight of the human aspect of psychology. I don't believe that human emotional experience can just be treated as a variable to create one simple formula (e.g.: depression + CBT = recovery) that fits in every instance. Although humans studying the human mind presents a dilemma in terms of objectivity, as a clinician I think this position is an asset, allowing connection and empathy. I think the strength of clinical psychology is the ability to draw on understanding from available evidence in combination with individualised care considering the many different factors that may affect a person's experience, within the context of an empathic therapeutic relationship.

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Appendix A

Parent Letter

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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 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 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 have also enclosed an information leaflet, which describes our research in more detail. If we still have a current contact number for you then we will give you a quick phone call soon to see if you are interested in hearing more about the study.

Please do not hesitate to contact us if you would like to discuss the study further in the meantime. It would be great if you could let us know whether your child would be interested in taking part - you can contact us on 020 7794 2313, or Hannah.Larkin@annafreud.org.

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

Yours faithfully,

Hannah Larkin   Samantha Taylor-Colls

Appendix B

Study Information Sheet

Anna Freud Centre

PARENT/GUARDIAN INFORMATION SHEET

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 Hannah Larkin on 020 7794 2313.

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 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 a computer game. 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, to look at some cartoon drawings and to do their own drawing. We won't ask your child to wear the EEG net whilst they are doing these things. 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.

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. Hannah or Samantha (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.

Please note that we ask you, or the person who brings your child, to remain with them at the Anna Freud Centre for the duration of the study appointment. It is Anna Freud Centre policy that children of this age are accompanied by an adult whilst participating in research.

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 (approval: 0384/096).

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 Hannah Larkin on 020 7794 2313. If you prefer to email, you can contact us on Hannah.Larkin@annafreud.org.

Thank you for taking the time to read this information sheet

Appendix C

Child Invitation Letter

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

Caring
for young
minds

Anna Freud Centre

Hello,

We are Hannah and Samantha and we are writing to you from the Anna Freud Centre.

We are really interested in meeting you because you came with your mum when you were a baby and we would like to find out how you are getting on now.

We thought you might like to hear a bit more about what happens when children come and help us with our research.

In our research, we ask children to play one game on the computer, and one game with some playmobil people.

The game on the computer is watching some cartoon stories and thinking in your head about them.

For this game, we would like to measure your brain waves. Luckily, we can do this without looking inside your head by measuring them from the outside.

To do the measuring, we ask you to wear a hat that looks a bit like this:

Sometimes babies wear the hats too!

The other game is one with playmobil people like these:

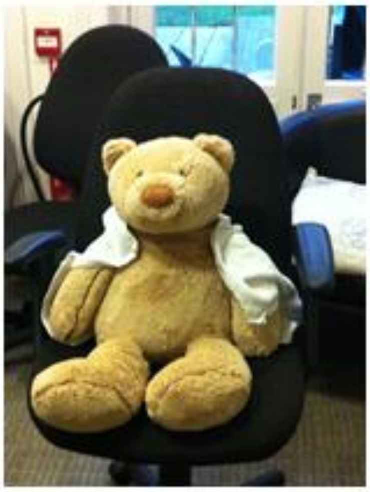
We start to tell a story with the people, and then ask the children to finish the story.

We don't ask children to wear the hat for this game. Instead, we make a video with a videocamera so that we can remember what happened in the stories.

We thought you might like to hear about what would happen if you came to join in our research:

First, families come and sit here and ask any questions about the games or what is going to happen.

Then the child comes and sits on this chair so that we can put the hat on:



Mums or dads can come too! Sometimes families take a picture of the child wearing the hat to take to school for show and tell.

Once we have put the hat on, we will check if you are OK.

Sometimes it can be a little bit itchy but we can help to get it comfortable.

Most children say it is better than a swimming hat!

Then we ask children to sit and play the computer games:

While you play the games, we will look at your brainwaves on the computer. They will look like this:

After the computer games, we play the game with the playmobil.

Children can take a break any time they need to. We have snacks and drinks:

We give children a £5 book token to say thank you for helping us. We are really grateful when children help us because it means we can find out more about how children learn.

Thank you for reading this letter. Do you think you would like to come and take part?

If you have any questions or worries, then you can phone 020 7794 2313 and ask to speak to Hannah.
Or, you could ask your mum or dad to email us: Hannah.Larkin@annafreud.org.

We look forward to hearing from you!

Appendix D

Confirmation Letter

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

Caring
for young
minds

Anna Freud Centre

Dear

Thank you for agreeing to take part in our research study at the Anna Freud Centre's Development Neuroscience Unit. This letter is to confirm the timing of your appointment. Please also find enclosed an information sheet for the study, a consent form, a demographics form, and parent questionnaires. You can complete the enclosed documents before the session and bring them with you – or you can complete them at the Centre. If you, the parent, are unable to personally accompany your child on the day, we ask that you complete the consent form and questionnaires in advance. If you have any difficulty completing the questionnaires, please do not hesitate to contact us.

Your child's session has been booked for:

Time:

Day:

Date:

Location: Anna Freud Centre, 12 Maresfield Garden, London NW3 5SU

When you arrive please inform reception that you are here for the EEG study. The session will last approximately 2 hours. Please could you ensure that your child's hair is recently washed and dry with no product (styling gel etc) on.

Please do not hesitate to contact us if you have any questions, need to cancel, or to reschedule. You can contact us on 020 7794 2313, or hannah.larkin@annafreud.org.

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

Yours faithfully,

Hannah Larkin

Appendix E

Consent Sheet

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 tick 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: ____

____

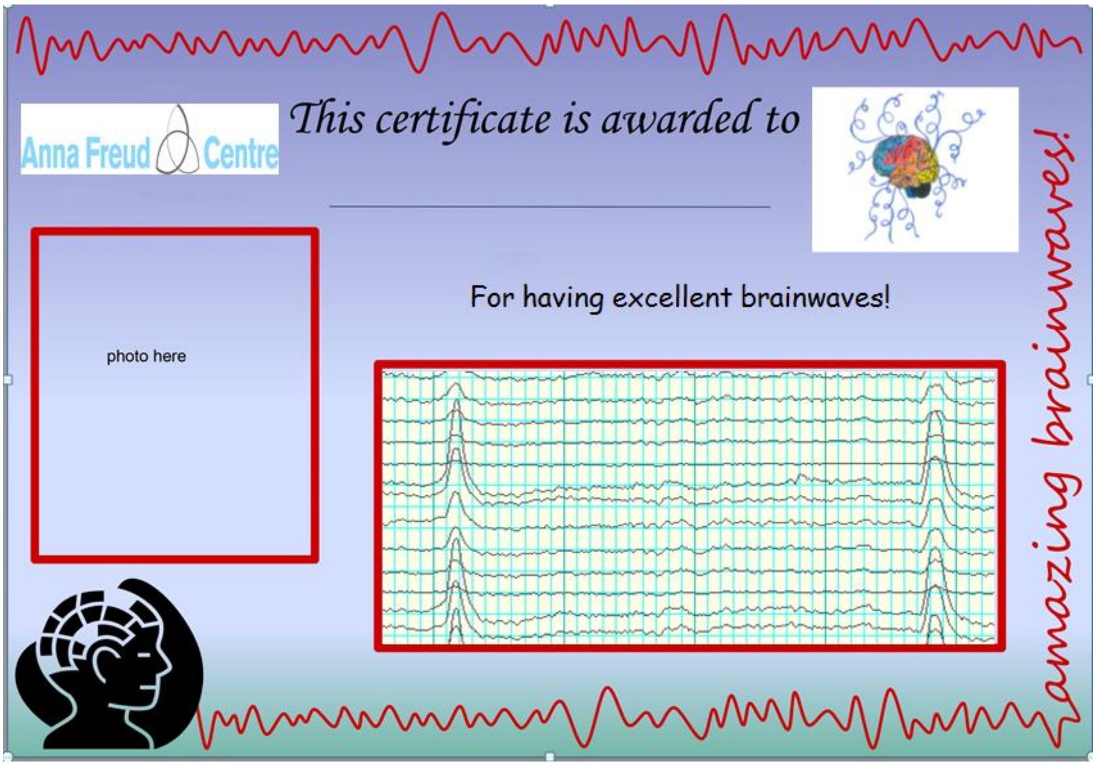
Telephone number: ______________________

Email: ______________________

1

Appendix F

Certificate


Anna Freud Centre
This certificate is awarded to
For having excellent brainwaves!
photo here
amazing brainwaves!

Appendix G

Emotion Stories

Positive Emotion Stories

(Congruent outcome: positive emotion. Incongruent outcome: negative emotion.)

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. 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?

6. 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?

7. 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?

8. 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?

9. 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?

10. 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?

11. 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?

12. 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 Emotion Stories

(Congruent outcome: negative emotion. Incongruent outcome: positive emotion.)

1. 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?

2. 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?

3. 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?

4. 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?

5. 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?

6. Homework

a) Daisy is watching TV with her brother

b) Mum comes in and tells Daisy 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?

7. 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?

8. 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 Callum can't reach it. I wonder how Callum is feeling? Shall we see?

9. 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 Joseph is feeling? Shall we see?

10. 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 tries to show mum but mum is too busy feeding the baby. I wonder how Poppy is feeling? Shall we see?

11. 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 tries to show mum, but mum is too busy on the phone to look. I wonder how Rebecca is feeling? Shall we see?

12. 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 H

Physical Stories

Physical Stories

1. Ball in tube

a) “Ellie and Lauren are playing ball” (with a blue football sized ball)

b) “Ellie rolls it through the tube. I wonder what will happen next? Shall we see?” (Ellie is standing at one end of the tube, Lauren at other end, see ball disappearing into Ellie’s end of the tube)

Expected: The ball comes out of the other end of the tube by Lauren

Unexpected: The ball appears below the tube in the middle

2. Seesaw

a) “Kate and Jen are playing in the park”

b) “They sit on the seesaw” (level)

c) “Steve comes to sit on the seesaw next to Jen. I wonder what will happen next? Shall we see?”

Expected: Seesaw drops at the end with Jen and Steve

Unexpected: Seesaw goes up at the end with Jen and Steve

3. Doll’s hat

a) “Jean is playing with her dolls” (tiny dolls hat)

b) “She wants to wear her doll’s hat. I wonder what will happen next? Shall we see?”

Expected: Tiny hat is perched on the top of her head

Unexpected: Hat fits

4. Diving board

a) “Duncan is at the top of the diving board”

b) “He dives off the board” (close to the board, still high up)

c) “He reaches the water. I wonder what will happen next? Shall we see?” (hands close to water)

Expected: He appears underwater

Unexpected: He appears bounced back into the air

5. Apple tree (based on story by Sebastian et al., 2012)

a) “Sarah and Tim see an apple tree” (with lots of apples)

b) “They decide to shake the tree” (one person standing on either side of the tree)

c) “The apples start to fall. I wonder what will happen next? Shall we see?” (a few apples on the ground on each side of the tree)

Expected: Apples fall everywhere

Unexpected: Apples are all neatly on one side and none on the other side

6. Drinks (based on story by Sebastian et al., 2012)

a) “Dominic and Raj are having a drink”

b) “Dominic pours himself some more juice”

b) “Dominic has spilled his drink. I wonder what will happen next? Shall we see?”

Expected: Dominic has stained his jumper

Unexpected: Dominic and Raj have both stained their jumpers

7. Bath time

a) “Noah is ready to have his bath”

b) “He gets his rubber duck and puts it in the bath. I wonder what will happen next? Shall we see?” (holding rubber duck just above the waterline)

Expected: Rubber duck floats

Unexpected: Rubber duck sinks to the bottom of the bath

8. Vase (based on story by Sebastian et al., 2012)

a) “Louise and Rebecca are carrying a vase”

b) “They’ve dropped it!”

c) “It’s nearly hit the floor! I wonder what will happen next? Shall we see?”

Expected: Vase smashes

Unexpected: Vase bounces

9. Dog and ball

a) “Allan is playing with his dog Rover”

b) “Allan throws the red ball for Rover to fetch”

c) “Rover races after it. I wonder what will happen next? Shall we see?”

Expected: Rover returns with his red ball in his mouth

Unexpected: Rover returns with the string of a purple helium balloon in his mouth

10. Chicken

a) “Harriet is collecting the eggs from the chickens”

b) “Harriet picks up a big brown egg”

c) “Harriet trips and lets go of the egg. I wonder what will happen next? Shall we see?” (Harriet falling, egg flying through the air)

Expected: Egg has smashed

Unexpected: Egg has bounced

11. Hair

a) “Kim is getting ready for school” (long black hair, school uniform)

b) “Mum does her hair for her. I wonder what will happen next? Shall we see?” (mum brushing her long black hair)

Expected: Long black hair in ponytail

Unexpected: Long bright ginger hair in ponytail

12. Piggy bank

a) “Thomas keeps his pocket money in his piggy bank” (small piggy bank)

b) “His dad gives him five shiny coins”

c) “Thomas puts them in his piggy bank. I wonder what will happen next? Shall we see?”

Expected: Thomas has small piggy bank which is full with one of the coins sticking out of the slot

Unexpected: Thomas sits with huge stretched piggy bank with no coins visible

13. Tennis ball (Stairs)

a) "Andy is playing with his tennis ball"

b) "He bounces his ball in the hall"

c) "He bounces his ball down the stairs. I wonder what will happen next? Shall we see?"

Expected: Ball bounces all the way down the stairs

Unexpected: Ball cracks open like an egg into two pieces at the bottom of the stairs

14. Snowflake

a) "Ash catches a snowflake falling from the sky"

b) "He brings it indoors to show mum"

c) "He puts in on the table by the candle. I wonder what will happen next? Shall we see?"

Expected: Snowflake has melted into a puddle of water

Unexpected: Snowflake is still there and candle has gone out

15. Hill (Running)

a) "Anna is at the bottom of the hill"

b) "Laura is at the top"

c) "Anna is running up the hill. I wonder what will happen next? Shall we see?"

(Anna is halfway up the hill)

Expected: Anna and Laura are together at the top

Unexpected: Anna and Laura are together at the bottom

16. Balloon (based on story by Sebastian et al., 2012)

a) "Charlie has a balloon"

b) "Fatima has a pin"

c) "Fatima puts the pin right by the balloon. I wonder what will happen next? Shall we see?"

Expected: Balloon pops

Unexpected: Balloon bends under the pin

17. Weather (based on story by Sebastian et al., 2012)

a) “Tina and Mike are going for a walk in the sunshine” (no clouds, blue sky and sunshine)

b) “Clouds have appeared” (dark grey clouds)

c) “It starts to rain. I wonder what will happen next? Shall we see?” (light rain, dark grey clouds)

Expected: It rains heavily

Unexpected: It is bright and sunny with no rain

18. Sandcastle (based on story by Sebastian et al., 2012)

a) “Rosanna and Jim have built a sandcastle”

b) “A wave is coming closer to them”

c) “The wave goes right over their sandcastle. I wonder what will happen next? Shall we see?”

Expected: As wave recedes sandcastle is gone, just a pile of sand

Unexpected: As wave recedes sandcastle is still there

19. Snowman (based on story by Sebastian et al., 2012)

a) “Karl and Dean have built a snowman” (wearing hats and gloves, snow is falling, no sunshine)

b) “The sun comes out” (bright sunshine and blue sky)

c) “It’s getting hot. I wonder what will happen next? Shall we see?” (wearing t-shirts and trousers, snowman has shrunk to ¾ original size, grass showing through a bit of snow)

Expected: In the sunshine, flowers are out, no snow on the ground, snowman is almost completely melted

Unexpected: In the sunshine, flowers are out, no snow on the ground, snowman hasn’t melted

20. Puddle

a) “Joshua is playing in the rain”

b) “He jumps in a puddle. I wonder what will happen next? Shall we see?” (Joshua is in the air, mid-jump”

Expected: Splashes his wellies

Unexpected: Waterline is at his waist

21. Fishing

a) “Bruno is fishing with his dad”

b) “Bruno has caught something!” (line tight, rod starting to bend)

c) “He is pulling hard. I wonder what will happen next? Shall we see?” (lots of effort going into pulling it up, Bruno bending over, dad helping him, line very tight, rod almost bent in two)

Expected: Bruno has caught a really huge fish

Unexpected: Bruno has caught a tiny goldfish

22. Dad's shoes

a) “Rohan is playing with dad” (Rohan very small, dad very tall with big feet)

b) “Rohan decides to put on dad's shoes. I wonder what will happen next? Shall we see?” (Rohan’s small feet next to dad’s big shoes, dad’s big feet visible)

Expected: Shoes are much too big

Unexpected: Shoes fit perfectly

23. Rolling pin

a) “Annie is making biscuits with her mum” (both in aprons, big round ball of dough)

b) “Annie uses the rolling pin to roll out the dough. I wonder what will happen next? Shall we see?” (dough is spread into a partially flattened rough circle, still quite thick)

Expected: The dough is spread into a big thin circle

Unexpected: The dough is back as a big round ball of dough

24. Radio

a) “Nicki is listening to the radio” (medium sized musical notes come from speaker)

b) “Her mum tells her it is too loud”

c) “Nicki turns the volume down. I wonder what will happen next? Shall we see?”

(arrows to show she is turning the volume down)

Expected: Tiny musical notes come from the speaker

Unexpected: Giant musical notes coming from the speaker

Appendix I

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Appendix J

Demographics Sheet

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 and understanding social situations: An EEG study

Demographics Form:

Child's Name: ________________________________

Child's date of birth:____________________

Child is LEFT HANDED / RIGHT HANDED (delete as appropriate)

For the study it is important that we know if your child has any of the following:

- Hearing impairment YES / NO - If yes is this corrected by hearing aids? YES / NO
- Visual impairment YES /NO – If yes is this corrected by glasses? YES / NO
- Learning Disability YES / NO
- Autistic Spectrum Disorder YES / NO
- Metal or electrical implants or fragments YES / NO
- Any allergies YES / NO – if yes please give details: ____________________________

It is helpful for us to know a little bit about who is living at home with your child, including their name and age:

Parents:____

Brothers:____

Sisters:____

Others:____

Pets:____

Any other important family members who do not live at home:___________________________

____

1

Appendix K

SDQ 4-17 Parent Report with Impact Supplement

Strengths and Difficulties Questionnaire

P 4-17

For each item, please mark the box for Not True, Somewhat True or Certainly True. It would help us if you answered all items as best you can even if you are not absolutely certain or the item seems daft! Please give your answers on the basis of the child's behaviour over the last six months.

Child's Name .... Male/Female

Date of Birth..

	Not True	Somewhat True	Certainly True
Considerate of other people's feelings	☐	☐	☐
Restless, overactive, cannot stay still for long	☐	☐	☐
Often complains of headaches, stomach-aches or sickness	☐	☐	☐
Shares readily with other children (treats, toys, pencils etc.)	☐	☐	☐
Often has temper tantrums or hot tempers	☐	☐	☐
Rather solitary, tends to play alone	☐	☐	☐
Generally obedient, usually does what adults request	☐	☐	☐
Many worries, often seems worried	☐	☐	☐
Helpful if someone is hurt, upset or feeling ill	☐	☐	☐
Constantly fidgeting or squirming	☐	☐	☐
Has at least one good friend	☐	☐	☐
Often fights with other children or bullies them	☐	☐	☐
Often unhappy, down-hearted or tearful	☐	☐	☐
Generally liked by other children	☐	☐	☐
Easily distracted, concentration wanders	☐	☐	☐
Nervous or clingy in new situations, easily loses confidence	☐	☐	☐
Kind to younger children	☐	☐	☐
Often lies or cheats	☐	☐	☐
Picked on or bullied by other children	☐	☐	☐
Often volunteers to help others (parents, teachers, other children)	☐	☐	☐
Thinks things out before acting	☐	☐	☐
Steals from home, school or elsewhere	☐	☐	☐
Gets on better with adults than with other children	☐	☐	☐
Many fears, easily scared	☐	☐	☐
Sees tasks through to the end, good attention span	☐	☐	☐

Do you have any other comments or concerns?

Please turn over - there are a few more questions on the other side

Overall, do you think that your child has difficulties in one or more of the following areas: emotions, concentration, behaviour or being able to get on with other people?

No	Yes- minor difficulties	Yes- definite difficulties	Yes- severe difficulties
☐	☐	☐	☐

If you have answered "Yes", please answer the following questions about these difficulties:

• How long have these difficulties been present?

Less than a month	1-5 months	6-12 months	Over a year
☐	☐	☐	☐

• Do the difficulties upset or distress your child?

Not at all	Only a little	Quite a lot	A great deal
☐	☐	☐	☐

• Do the difficulties interfere with your child's everyday life in the following areas?

	Not at all	Only a little	Quite a lot	A great deal
HOME LIFE	☐	☐	☐	☐
FRIENDSHIPS	☐	☐	☐	☐
CLASSROOM LEARNING	☐	☐	☐	☐
LEISURE ACTIVITIES	☐	☐	☐	☐

• Do the difficulties put a burden on you or the family as a whole?

Not at all	Only a little	Quite a lot	A great deal
☐	☐	☐	☐

Signature .... Date ....

Mother/Father/Other (please specify:)

Thank you very much for your help

Appendix L

Ethical Approval

UCL RESEARCH ETHICS COMMITTEE
GRADUATE SCHOOL OFFICE

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

23 June 2014

Dear Professor Fearon

Notification of Ethical Approval
Project ID: 0384/096: The development of executive function and social understanding: an EEG study

I am pleased to confirm that your study has been approved by the UCL Research Ethics Committee for the duration of the study i.e. **until June 2015**.

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

[redacted]

Professor John Foreman
Chair of the UCL Research Ethics Committee

Cc:
Hannah Pincham, Applicant
Professor Peter Fonagy

UCL RESEARCH ETHICS COMMITTEE

Amendment Approval Request Form

1	**Project ID Number:** 0384/096	**Name and Address of Principal Investigator:** Professor Pasco Fearon, Research Department of Clinical, Educational and Health Psychology University College London Gower Street London WC1E 6BT
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) To allow a comparison of the EEG measures of emotion understanding with a behavioural measure of emotion understanding, a behavioural measure (the TEC) is being added to the proposal.	
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) One additional measure will be used to test the child's emotion understanding. The measure to be used is the TEC (Test of Emotion Comprehension) developed by F. Pons & P.L. Harris (2000 - unpublished). It involves children choosing the appropriate emotion face for each cartoon scenario in the TEC book and takes approximately 15minutes to complete with the support of a researcher. We have amended the information sheet accordingly (please see attached). References: F. Pons, P.L. Harris & M. de Rosnay. (2004) Emotion comprehension between 3 and 11 years: Developmental periods and hierarchical organization. European Journal of Developmental Psychology, 1:2, 127-152	
6	**Ethical Considerations** (insert details of any ethical issues raised by the proposed amendment/s) We do not anticipate that this study will cause distress to the participants. The addition of the TEC will extend the time the child is required for research by 15minutes. The TEC has been used in research with children aged between 3 and 11 years. If the child becomes distressed or asks to stop at any point during the study then they will be removed from the study. The data collected up to this point may still be used, if the parent consents for us to do so.	
7	**Other Information** (provide any other information which you believe should be taken into account during ethical review of the proposed changes) N/A	

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: [redacted]

Date: 3/07/14

FOR OFFICE USE ONLY:

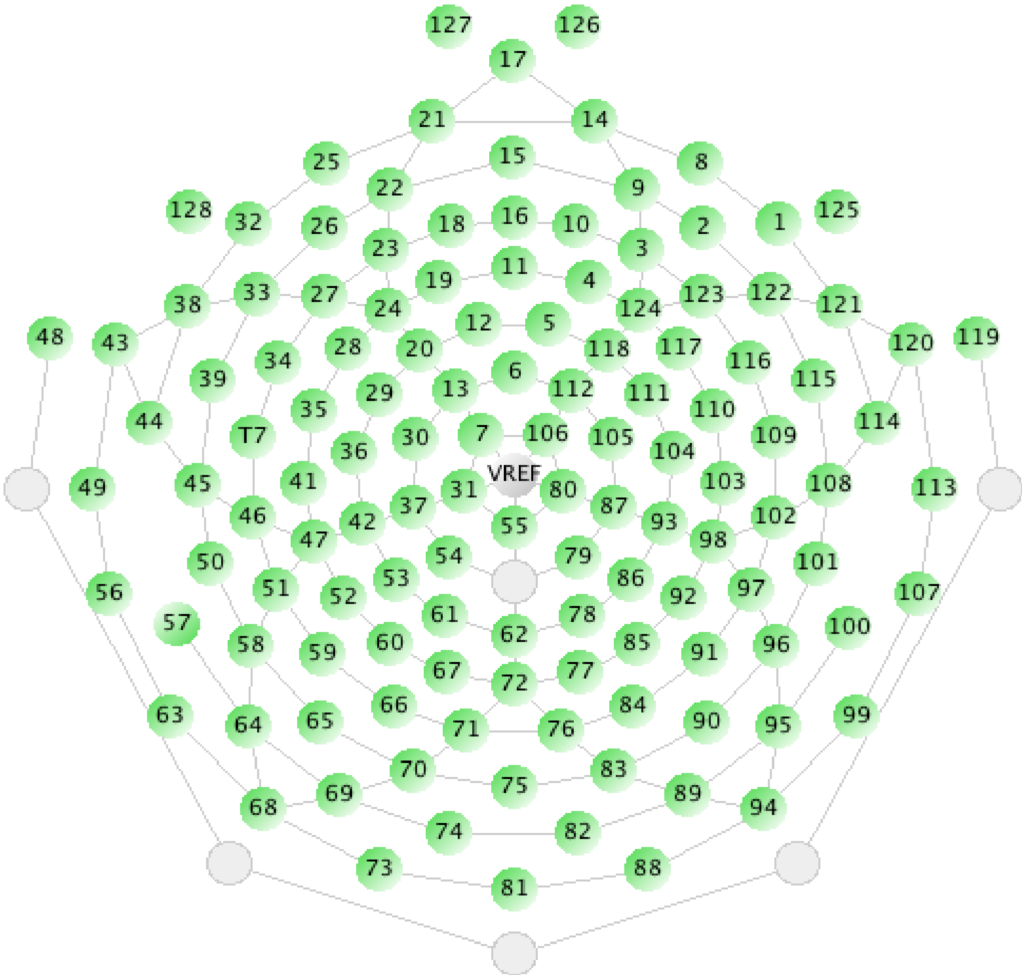
Amendments to the proposed protocol have been approved by the Research Ethics Committee.

Signature of the REC Chair, Professor John Foreman: [redacted].

Date: 7/7/2014.

Appendix M

Map of Electrode Locations



Note: VREF is electrode 129.