Investigating facial expression production and inner outer face recognition in children with autism and typically developing children

Ajanta Biswas

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University of Sheffield
Department of Psychology, Western Bank, Sheffield S10 2TP

Abstract

Behavioural and neuroimaging evidence suggests that autism is characterised, in part, by deficits in social intelligence. Impairments in face and eye gaze processing and facial expression recognition are often used to explain this deficit. Although the general consensus is that children with autism are impaired in face and facial expression processing the actual seat of impairment is unknown. Furthermore, face recognition using only inner face information and facial expression production without any visual cues has never been investigated in children with autism.

Research on the development of face recognition abilities provided mixed results with regard to how children identify unfamiliar faces both in typical and atypical populations. Recognising an unfamiliar face from only inner face has not been investigated during development or in children with autism. This thesis investigated unfamiliar face recognition from inner face only information firstly, during developmental period of 5-10 years of age; and secondly, with children with autism and individually matched controls. 5-10-year-olds were exceptionally good at face recognition from only inner face information. Children with autism were as good as the matched controls in recognising unfamiliar faces from only inner face information. These findings are discussed with reference to holistic face processing ability and perceptual sameness of the stimuli.

Research on the development of facial expression recognition indicates a differential pathway for different expressions both in typical and atypical populations. This thesis investigated facial expression production ability with and without context in children with autism and individually matched controls. Children with autism were atypical in fear facial expression production and failed to use context to enhance performance. These findings are discussed with reference to social intelligence and the role of experience in early childhood in development of face expertise.

Acknowledgements

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I would like to thank Olivier for being my mentor and supervisor. From the time I first came to Sheffield he encouraged, supported, guided and taught me everything I know about faces. I am amazed at his level of empathy, and patience for his students, his commitment to the field of research and his sense of humour.

This work would not be possible without the children who eagerly participated and patiently performed the tasks. They taught me about autism spectrum conditions more than any book could ever do. This work would not be possible without them and for that I am eternally grateful.

I would like to thank my family who supported me and cheered me all the way to the finish line. I could not have achieved anything without my boys.

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Contents

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Abbreviations

ASC	Autistic Spectrum Conditions
ERP	Event Related Potential
FE	Facial Expression
FEs	Facial Expressions
fMRI	functional Magnetic Resonance Imaging
FR	Face Recognition
HFA	High-Functioning Autism
MC	Matched Controls
MEG	Magnetoencephalography
TD	Typically Developing
TOM	Theory of mind
WCC	Weak Central Coherence

Chapter 1

Thesis aims and advance organiser

Abstract

This chapter states the primary aim of the thesis. Also as an advance organiser it lists what each chapter includes and why. I also explain the layout of the literature review and justify why each area is covered in the review.

1.1. Primary aims

The main aims of this thesis are three fold: Firstly, to investigate if children with autism, specifically the high functioning autism (HFA) children, are able to produce facial expressions (FEs) with and without context and label the six basic emotions in stories. To then compare this finding with a sample matched on a one to one basis for IQ and chronological age in order to investigate the group difference.

Secondly, to establish if children with autism use the inner face for identity recognition tasks thus demonstrating holistic processing. To compare this finding with a sample matched on a one to one basis for IQ and chronological age in order to investigate the group difference.

Thirdly, to determine the developmental pathway of holistic processing in typically developing children aged 5 to 9 using the inner face in the learning phase.

1.2 Advance organiser

Chapter 2 covers the literature on face recognition starting with brief synopsis of adult expertise in face processing followed by developmental pathway right from birth. This is to set the scene of face processing as the research reported here was investigating face recognition (FR).

Chapters 3 and 5 cover the literature on neural mechanisms known so far for face recognition and facial expression (FE) recognition. This is because the findings of this thesis fit in with both behavioural and neural models of face processing. Furthermore the research reported here was specifically investigating FE processing in autism population. Autism has benefited from considerable attention from neuroscientists and the findings of this research are explored within the neuroscience models of autism as well. Hence reviews of typical neural system for face processing and FE processing are included in this thesis.

Chapter 4 covers the literature on development of facial expression recognition along with factors influencing FE perception. This is because the main purpose of this thesis was to investigate FE and the factors stated in literature so far were taken into consideration when designing experiments.

Chapter 6 covers diagnosis of autism from clinical and research perspectives. For the purpose of this research I acquired training in diagnosing autism for research purposes. Diagnosis of autism from clinical and research perspective is very varied and has implications on the findings of research. Taking this into account diagnosis of autism is explored especially from research perspective. Literature on face processing and FE processing in the autism population is covered here

Chapter 7 covers literature on inner outer face recognition because this paradigm is used to investigate FR in children aged 5 to 10 years of age in this thesis.

Chapter 8 states the primary and secondary aims of thesis in detail and how the aims are achieved before embarking on the experiments of the thesis.

Chapter 9 reports the experiments on inner outer face recognition and discusses the findings.

Chapter 10 reports the experiments on FE recognition and discusses the findings.

Chapter 11 covers general discussion where by the main findings of this thesis are stated and considered thus bringing the FR and FE findings together.

1.3 Layout and justification of literature review

It is vital that this research is set in context within the existing literature of face and facial expression (FE) processing for typical individuals as well as the autism population. A backdrop of FR and FE recognition in the typical population is first presented in the review in order to set the developmental pathway. The general consensus among scientists working in the field of face research is that adults are experts in processing face stimuli. Scientists have then investigated when does this special ability emerge in infancy. The literature review included in this thesis follows this path in order to highlight the developmental pathway. This is essential because it is only when I fully explore and understand what the developmental pathway is for the typical population, that I can evaluate the developmental pathway for the autism population. Also for this evaluation to be effective it is essential to have a good understanding of the pervasive developmental disorder from diagnostic and theoretical points of view. Hence the second part of literature review covers autism diagnosis and theories followed by behavioural evidence of FR and FE recognition.

Autism is considered a neuro-developmental disorder and has benefited from research within the field of neurophysiology. Scientists investigating expertise in face processing have also extensively used neurophysiological technology in order to answer if face processing is domain specific or domain general. Although the research reported in this thesis has not employed neurophysiological techniques for investigation the findings of this research links in very well with the neural system model. Therefore, when reviewing FR and FE recognition evidence from neuroscience is presented demonstrating that face processing and FE processing is domain specific from later stages of childhood.

Chapter 2

Face recognition

Abstract

In this chapter I take the following route: firstly, I demonstrate that, adults *are* face experts, then consider two of the processing concepts, namely the holistic and configural. I then explore the notion that individuals use different processing strategies at different stages of life. The final section summarises three theories on the development of face recognition (FR). In this chapter and throughout this thesis information on adult literature is presented to draw home the point that typical adults are 'face experts'. Information on the infant literature is also presented in order to chart the developmental pathway for face processing from birth to adolescence.

2.1 Faces are special, adults are experts

Infants right from birth, encounter other human faces more often than any other visual object, and of a wider range. Faces are by far the most complicated visual stimuli that any newborn will encounter and are undoubtedly the most important stimuli category for survival. Newborn infant with very limited visual acuity finally gets to the stage where, as an adult, he has to extract information in a matter of milliseconds, and effectively infer gender, identity, mood, emotion, age and mental states of the face he comes across. Faces are highly salient and biologically significant visual stimuli that provide information critical for successful negotiation of the social world (de Haan et al., 2002).

Faces are a remarkably homogeneous class of visual stimuli; they share a highly similar structure, always consisting of the same set of parts (eyes, nose, mouth, ears) in the same basic configuration (nose below the eyes and above the mouth etc.).

Despite this adults can typically recognise faces more quickly and more accurately than other types of visual stimuli (Yin, 1969) and are classed as 'face experts'. Having drawn the conclusion that adults are 'face experts' the big question has been, how we become expert in processing faces? In order to answer this question to any satisfaction, research in this field has approached the scrutiny of expertise from numerous angles. Some researchers have made the comparison of faces as stimuli with other classes of stimuli such as houses, cars, dogs etc.; others have manipulated the face stimuli into a variety of atypical formats such as inversion, changing the location of features, changing the distance between the features etc. Comparison of adult data has also been consistently and relentlessly made to developmental data to demonstrate the expertise. Numerous behavioural, biological, evolutionary, and neurological theories and processing concepts have been proposed in order to explain the expertise. As a result, the literature of face recognition is awash with endless small claims of significant differences between children and adult face processing ability, between different processing mechanisms, all resulting in a final single main claim – face processing is unique and we as adults are 'experts' in it.

2.2 Faces are not special

Gauthier and Tarr, (1997) designed novel objects called 'Greebles', a homogenous class of stimuli created to share the properties of a human face (see Figure 2.1). Using these stimuli the authors first trained novices to become 'Greeble experts' and then tested them for holistic processing. It was reported that Greebles were processed more holistically by experts than novices and an inversion effect was observed when inverted Greebles were presented to Greeble experts.

(a)

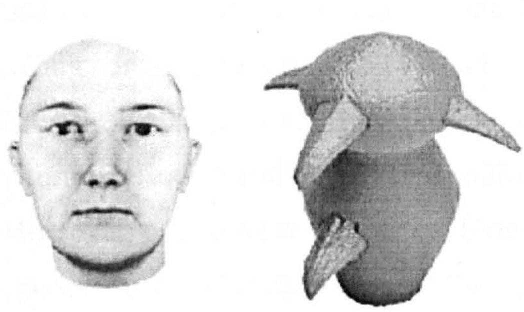


Figure 2.1: Example of greebles designed to test the effect of expertise. Reproduced from Gauthier, Behrmann and Tarr, (2004).

It is asserted that holistic processing and an inversion effect relates to expertise with a stimulus category and that faces are not necessarily 'special' in the way they are processed (Gauthier et al., 2004; Carey and Diamond, 1986).

An alternative explanation for the 'Greeble effect' has been that the configuration of Greebles is so similar to the human face that it inadvertently triggers face-selective visual processes (Kanwisher, 2000).

2.3 Familiar and unfamiliar face

Everyone processes familiar faces differently to unfamiliar faces. Adults, as face experts, generally rely more on the internal and hence stable features in identity recognition tasks; whereas children tend to rely more on the external features for processing face stimuli (Ellis, Shepherd and Davies, 1979).

For the purposes of this thesis the term 'familiar face' has been used to describe faces that are learnt as part of everyday life and the term 'unfamiliar face' has been used to describe faces that are otherwise not known to individuals but have been familiarised only for the purpose of research. Since my main work and investigation involves unfamiliar faces, I restrict my review to unfamiliar faces throughout.

2.4 Evidence of face expertise in adults

Carey, Diamond and Woods, (1980) state that an adult's capacity to recognise faces has two aspects: 'encoding an unfamiliar face', which involves forming a representation of the face, then 'recognition', referring to the matching of the representation previously formed. Both encoding and recognition are done extremely effectively and rapidly. Moreover, once a representation is formed and stored it stays in the memory for a long period of time (Bahrick et al., 1975).

Another way to demonstrate the existence of expertise has been to test the 'inversion effect'. FR is adversely affected in terms of both accuracy and reaction time when faces are inverted through 180°; known as the inversion effect. Importantly, the reduced level of accuracy observed for inverted faces is not seen for other mono-oriented objects, such as cars or houses etc. (e.g. Yin, 1969). These early findings led authors to speculate that there might be something 'special' about faces: "the inverted face is especially difficult to remember because of two factors: a general factor of familiarity with mono-oriented objects and a special factor involving only faces" (Yin, 1969; p. 145). This inversion effect was also verified by Diamond and Carey (1986), with adult participants, who were presented with inverted faces, landscapes and dog shapes. Adults succumbed to inversion effects as far as faces are concerned but not so much for landscapes, however, participants who were experts in dogs, succumbed to inversion effect with dog shapes as well as human faces (see figure 2.2). This study emphasised that adults definitely have expertise in faces and as a result are affected by the inversion of faces. Furthermore, if adults are experts in any other class of stimuli they would be as affected in that class of stimuli as the face inversion.

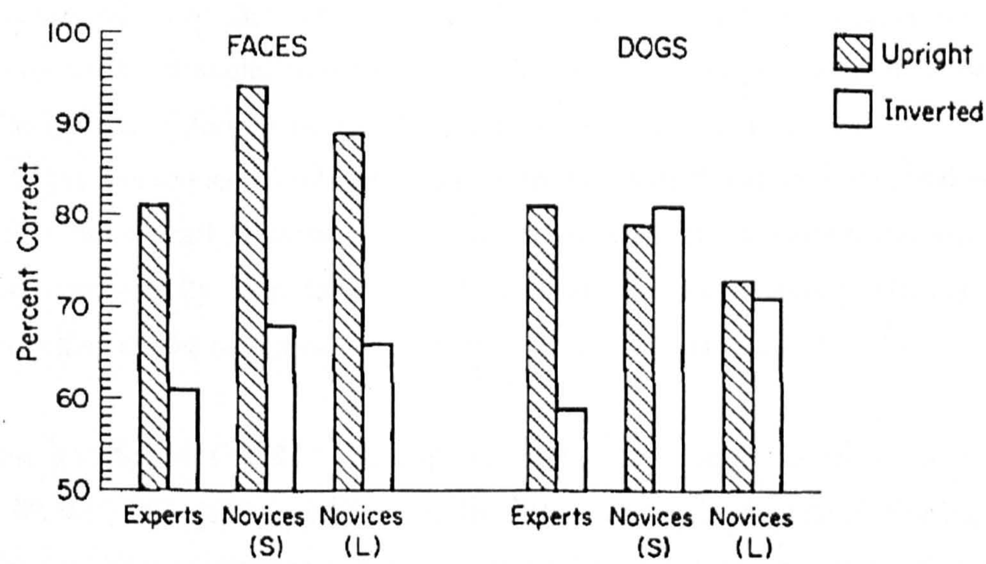


Figure 5. Performance of experts and novices on faces and dogs presented upright and inverted in Experiment 3. Novices (S) were given a small set size on dogs, whereas novices (L) were given the same large set size as were experts.

Figure 2.2: Taken from Diamond and Carey, (1986) which highlights that individuals who are dog experts are affected by an inversion effect for dog shapes.

2.4.1 Dual processing hypothesis

Diamond and Carey, (1986) tried to explain the inversion effect by suggesting that we should distinguish between first-order and second-order relational information. First–order relational information describes the basic configuration of a stimulus, and is used to classify a face as a face (e.g. eyes above nose above mouth). Second-order relational information reflects variations of this basic configuration in terms of the distance between the features (e.g. eyes wide set for a narrow face). Diamond and Carey, suggest that when faces are inverted, people are unable to efficiently extract second-order relational information and revert to a less accurate featural processing strategy. It should be noted here that second-order relation as described by Diamond and Carey, (1986) is now more popularly known as configural processing as later described by Maurer, Le Grand and Mondloch, (2002).

2.4.2 Single Processing Strategy

An alternative account to the dual-processing hypothesis, to explain the 'inversion effect' is that faces are processed using a single strategy. According to this account, because faces are typically seen in an upright orientation, they can only be processed in the canonical view; therefore the image being viewed must be mentally rotated back to its canonical angle. However, as the degree of rotation increases, it becomes harder to accurately form a mental representation of the face using configural cues (Rock, 1973). Consequently, a linear relationship should be found between the degree of rotation and overall performance. However, stimuli from categories that are not processed configurally (e.g. tables, fruit etc.) shouldn't be adversely affected by rotation as they can be recognised accurately regardless of angle (e.g. Yin, 1969).

Valentine and Bruce, (1988) found support for this account using faces that were rotated 0°, 45°, 90°, 135° or 180° away from the canonical orientation (See Figure 2.3). They found a significant linear relationship between the angle of rotation and reaction times. Importantly, they did not find such a relationship when subjects were required to perform the same task with objects.

Figure 2.3: Examples of human face stimuli rotated at 0°, 45°, 90°, 135° and 180°, constructed using samples of face stimuli from our lab at Sheffield University .

Expertise in FR in adults has been demonstrated using the 'inversion effect' paradigm. The reason performance is affected in terms of accuracy and reaction times could be interference in configural processing or it could be "speed trade off" because of time taken in rotation of the canonical view. The reasons for such poor performance here is not as important as noting that FR in adults is at expert level and inversion affects such expert level performance.

2.5 Configural and holistic processing

The first process in FR is to recognise a face as being a face and this is essentially called *first-order processing.* Once we have identified a stimulus as a face then we endeavour to identify the face. This entails processing more information, such as the salient features, as well as the distance between these features. These are called *featural* and *configural processing* respectively. Maurer et al., (2002) describe configural processing as sensitivity to second-order relations i.e. perceiving distances between features. The inversion effect paradigm is one of the ways to test configural processing strategies in operation. Later in the chapter other paradigms used to investigate configural processing will be presented and discussed.

Another type of processing that has been described in face processing is *holistic processing* which means glueing together the features (and the distance between them) of the face into a gestalt. Galton, (1879) proposed the idea of holistic processing in FR, noting that we do not perceive and analyse facial features separately; instead the face is processed as a whole unit. The whole idea of a gestalt is that the 'whole' is more than merely the sum of its parts, so the face gestalt perception is more than perceiving the individual features and the distance between them and.

The terms *configural* and *holistic* processing were previously used interchangeably by some authors (and are still at times used loosely by some researchers), but it is generally acknowledged that they are two subtly different processing strategies. For the purpose of this thesis I have attempted to keep the distinction between configural and holistic as is in holistic face processing literature, and review the literature, bearing this difference in mind. So for the purpose of this thesis configural processing refers to a face processing strategy that perceives spatial distance among features including changes in these distances and not the salience of the individual features such as big eyes or crooked mouth etc. Holistic processing refers to a face processing strategy that glues together the features into a gestalt resulting in the face being perceived as a whole not just perceiving the individual features or just distance between the features and changes in such distances. Maurer et al., (2002) uses a similar definition of configural and holistic face processing whereas; Tanaka and Farah, (1993); De Heering, Houthuys and Rossion, (2007), Campbell et al., (!995, 1999) all use the terms configural and holistic and salience of features interchangeably. In several situations it is difficult to distinguish whether an individual uses configural or holistic processing, which explains some of the inconsistencies in the literature. Operationally, I consider that the use of inner outer manipulation is a particularly clear method, and this is the one I focus on in this thesis.

2.6 Adults' research

2.6.1 Holistic face processing in adults

When any claims are made about holistic face processing, it is clear that holistic and featural processing is not a strict dichotomy, more a case of which one is used more than the other. Adults will recognise a face as long as at least one type of information is available, when faces are blurred, inverted, scrambled or inverted and scrambled adult performance in FR does not fall below chance (Collishaw and Hole, 2000; Mondloch, Dobson, Parsons and Maurer, 2004). Thus, in holistic face processing studies, the objective is to demonstrate merely that holistic processing is used by adults more than featural processing.

The experimental paradigms used to test holistic face processing are the whole-part paradigm (Tanaka and Farah, 1993) and the composite face paradigm (Mondloch et al., 2007; De Heering et al., 2007).

2.6.2 The Whole-part paradigm

In the whole-part paradigm, participants are familiarised with a group of faces and then asked to recognise individual facial features that are either embedded in a whole face or displayed independently (Tanaka and Farah, 1993). For instance, participants are presented with a face identified by a name, say 'Larry'. After an interstimulus interval participants are either presented with the same whole face along with a foil which differs by only one feature (and the question would be 'which one is Larry?'). Alternatively, participants are presented with one feature of the original face along with one foil feature in isolation (and the question would be 'which one is Larry's nose?') (See figure 2.4). If the participant processes the face holistically then a feature presented in the context of the whole face would be recognised more readily than when presented in isolation. This prediction was borne out in three experiments reported by Tanaka and Farah, (1993): participants were more accurate in identifying the parts of faces, presented in the whole face, than they were at identifying the same part presented in isolation, even though both parts and wholes were tested in forced-choice format and the whole face differed by only one part. In contrast, scrambled faces and houses did not show this advantage for identification of one part within a whole object.

Figure 2.4: Example of whole-part face stimuli. The nose is presented within the context of the face or in isolation during the recognition phase. Reproduced from Tanaka and Farah, (1993).

2.6.3 The Composite face effect

In the composite face paradigm, the top and bottom of two different but familiar faces are presented; either aligned or misaligned. The participant's task would be to make judgements upon whether the resulting face is the same or different. It is well established that when the top and bottom half of two different but familiarised faces are aligned, participants view it as a new face and struggle to see it as parts of two familiar but different faces. Participants are less accurate and have slower reaction times when the composite faces are upright and fused than when they are misaligned or inverted (Young, Hellawell and Hay, 1987).

The composite face effect has been considered as the most convincing evidence of holistic processing (Maurer et al., 2002) because it clearly demonstrates that individuals glue together separate face components for holding in their memory, and that faces are remembered as a whole, not as individual features. Carey and Diamond, (1994) presented adults with experimentally familiarised composite and non-composite faces in upright and inverted orientation. It was found that composite upright faces were more difficult to identify than the non-composites as reflected both in accuracy and reaction times and this difference disappeared for inverted faces. The composite face effect certainly reflects holistic encoding of faces when upright, the parts of a face are less accessible than are the whole faces (Carey and Diamond, 1994). This phenomenon demonstrates that when upright faces are processed, the internal features are so strongly integrated that it becomes difficult to parse a face into isolated features, especially when faces are presented for a very short interval, preventing a feature by feature comparison (Hole, 1994).

Suzuki and Cavanagh, (1995) claimed that the strength of holistic processing was evident even a line drawing of face was used when instead of an actual face stimulus. This experiment brought to light that adults have a strong tendency to glue the internal features of the face together so meaningless stimuli may stand at risk, to be classified as a face because of our ability to process the face holistically.

It is not just the internal features that get glued and processed as a whole. The internal features get holistically processed along with the external contour (Young et al., 1987). If the internal features are presented in two different face contours then adults tend to see the faces as two different faces and fail to see that the internal features are exactly the same. This phenomenon of glueing inner features to an external contour and perceiving it as a novel face is a result of holistic processing (Maurer et al., 2002; Sinha and Poggio, 1996), and will be covered extensively within chapter 7. Composite faces that use only the inner face to align and misalign perhaps do not explore holistic face processing completely. Another paradigm, namely 'switch face', if used in conjunction with composite face effect, will enable researchers to explore holistic face processing in its entirety.

Both the whole-part paradigm and the composite face paradigm lay bare the fact that adults have an overwhelming tendency to process faces holistically.

2.6.4 Configural processing

Adults can detect the variation in the distances between facial features very efficiently and are able to perceive a person's emotions, facial expression, mood and intentions. To evaluate configural processing, face stimuli are created that vary only in the spacing of individual features or face stimuli that have exactly the same spacing distance, but the individual features vary. These manipulated faces are then presented in upright and inverted orientation for discrimination or recognition tasks.

Freire, Lee and Symons, (2000) tested adults with versions of a single face that either differed in the shape of individual features or the spacing between features. Inverting these faces disrupted adults' ability to discriminate faces in the spacing set, but not in the featural set. Similarly, Leder and Bruce, (2000) tested adults FR by using configural face stimuli; inversion disrupted adults' ability to correctly identify faces from a study set when faces differed in the spacing set but not when the characteristics of local features were different. As a consequence of results such as these it has been inferred with confidence that adults rely on configural information in a face and are able to process this information instantly and anything that hampers the perception of spatial information affects performance.

Another technique for investigating configural face processing is blurring the stimuli to remove the fine detail featural information. Adults are able to recognise the identity of blurred face with reasonable accuracy (Maurer et al., 2002). Collishaw and Hole, (2001) presented adults with a blurred faces at various angles of orientation. When the blurred faces were in an upright position, accuracy was well above chance. The further the face was oriented away from upright, the lower the accuracy, meaning greater difficulty in extracting configural information.

The configural processing paradigm uses atypical faces in order to draw home the point that when adults process face stimuli for identification, recognition and perception of facial expressions, mood, intentions etc., they use configural processing strategies, and inversion hampers use of this strategy effectively.

So far I have focussed on adult expertise and the processing strategies availed by them, now I turn my focus to developmental research in the field of FR.

2.7 Infants research

Seminal work by Fantz, (1963) successfully indicated that faces are highly attractive stimuli for newborns. Babies as young as four days old show great interest to a schematic human face as opposed to a scrambled face. Goren, Sarty, and Wu, (1975) were the first researchers to directly test face preference behaviour in newborn infants. In their experiment, they looked at newborns' interest in three types of stimuli: a face, a scrambled face and a blank image, all of which were mounted on paddles (See figure 2.5). They found that both eye and head movements were greater for the face stimuli, exhibiting newborns interest in face-like patterns over and above other stimuli. Johnson, Dziurawiec, Ellis and Morton, (1991) replicated the findings of Goren et al., (1975) with a few refinements and reported that a moving face like pattern elicits greater tracking behaviour than a non-face like pattern or a blank head shape.

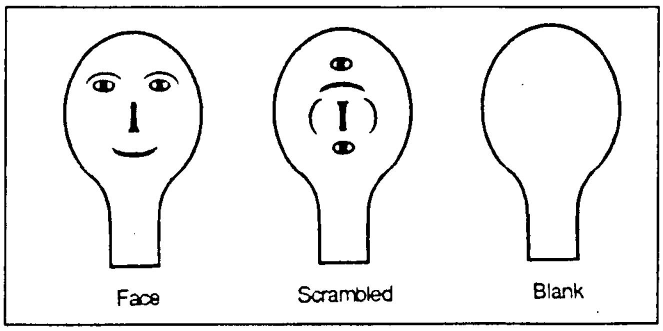


Figure 2.5: Stimuli used by Goren, Sarty and Wu. (1975). Reproduced from Johnson et al., (1991).

Further studies by John Morton and Mark Johnson which led to one of the most popular models on infant face processing will be presented in detail under the proposed model for FR.

In the first few days of life, initial recognition of the mother's face is dependent on the external parts of the face as reported by Pascalis, de Schonen, Morton, Deruelle, and Fabre-Grenet, (1995). By 4 months, infants show processing of their mother's face from both internal and external face parts in isolation to each other (Bartrip, Morton, & de Schonen, 2001). By 7 months infants show signs of utilising configural information with the finding that they respond to a 'switched' face (Cohen & Cashon, 2001). This 'switched face' and the findings of Cohen and Cashon, (2001) are discussed in detail in chapter 7 under inner outer face processing. The purpose of mentioning it here is merely to consolidate the idea that infants have the ability to discriminate faces at a very young age.

In addition to investigating face preferences of newborns using their mother's face, a handful of studies have investigated the ability of newborns to recognise unfamiliar faces. The novelty preference task used for testing recognition of unfamiliar faces involves habituating the newborn to a single face and then presenting two faces; the familiar face paired with a novel face. Infants prefer novel stimuli and it is this preference that the habituation task exploits. If infants discriminate between the images and shows greater interest in the novel face then the novelty preference is taken as evidence of recognition. Pascalis and de Schonen, (1994) were the first to directly investigate recognition abilities in newborns. They found that recognition, as indexed by a novelty preference, was observed following familiarisation to an unfamiliar face. Recognition was demonstrated after no delay and also after a 2-minute delay. This is an impressive finding as it demonstrates that infants can recognise faces which do not hold special significance.

On the whole it can be claimed with conviction that newborns have the ability to perceive face stimuli and discriminate the mother's face from other faces (Pascalis et al., 1995; Bartrip et al., 2001). By the age of 7 months infants can do configural processing (Cashon and Cohen, 2001) to a limited extent and finally infants can recognise unfamiliar faces (Pascalis and de Schonen, 1994).

2.8 Childhood research

In spite of impressive beginnings, FR undergoes protracted development (Carey, 1992) FR has been reported to improve with age from five to adulthood with some studies reporting a dip during adolescence (Chung and Thomson, 1995). The development of FR research has clearly shown that older children (12 years) are better than younger children (6 years old), (Carey, Diamond and Woods, 1980) and while there is no doubt that this ability improves with age there has been much debate as to the underlying processes that cause such a difference. Empirical evidence shows that there are fundamental differences the way younger and older children perceive and remember faces.

Carey and Diamond, (1977) showed to 6, 8 and 10 year olds upright and inverted faces. Immediately after seeing the faces they were asked to identify the previously seen face, classed as an 'old face', alongside a novel face, classed as a 'new face'. They found that 8 and 10 year olds, like adults, recognised the 'old face' better when they were upright than when they were inverted. However, accuracy for 6-year-olds for both upright and inverted faces was similar. This finding led them to hypothesise that younger children use featural processing and then at around the age of 10 they switch to holistic processing. They called this the 'encoding switch hypothesis'. Carey and Diamond, (1977) verified their own hypothesis by testing again 6, 8 and 10 year olds for FR task across faces that changed in paraphernalia (e.g. hairstyle, hat, glasses) and facial expressions. They found that 6-year-olds were more often misled by paraphernalia and facial expressions than 8 and 10 year olds. This finding enabled them to reinforce their encoding switch hypothesis which claimed that younger children are not as efficient in executing configural processing.

The encoding switch hypothesis has been since challenged by numerous researchers (Flin, 1985; Valentine, 1988) and the final conclusion has been it is not so much that featural and holistic processing is an absolute dichotomy it is more a case of which strategy is used more (Tanaka and Farah, 1993).

2.8.1 Whole-part paradigm

Tanaka, Kay, Grinnell, Stansfield and Szechter, (1998) tested 6, 8 and 10 year olds using a whole-part paradigm both with upright and inverted faces. The authors reported that 6-years-olds were able to better recognise face parts when presented in the context of a face rather than in isolation. Also, the holistic advantage remained stable from the age of 6 to 10, and while older children were better in general compared to younger children this relative difference was stable for both conditions. It was concluded that children process faces holistically and the holistic advantage is maintained through adulthood. When the faces were inverted the holistic processing of all age groups was disrupted. Taken together these results indicated that contrary to the encoding switch hypothesis children as young as 6 years of age process faces holistically.

2.8.2 Inner outer face effect

Another paradigm to test the developmental trend of greater reliance on holistic processing with increasing age has been inner outer face processing. Here the hypothesis has been that younger children because they depend more on facial features (Carey and Diamond, 1977) will tend to focus on outer facial features such as striking hairline, ears, chin etc.; whereas older children and adults will rely on the information provided by the inner face i.e. eyes, mouth and nose area. . Thus a younger child processes faces more from the outer face and as the person gets older this switches to inner face processing and a perceptual shift. Thus when younger children are presented only with an inner face, performance in face identity is worse in comparison to older children and adults. The inner outer face paradigm has been used not only to demonstrate holistic processing but also to show a qualitative shift from featural processing of outer face to holistic processing using the inner face.

Inner outer face processing paradigm is covered in detail in chapter 7.

2.8.3 Composite face paradigm

Carey and Diamond, (1994) used composite faces to test 6, 8 and 10 year olds and found that a holistic face processing strategy was operating in 6 year olds as much as in adults. This resulted in the conclusion that 6 year olds succumb to the composite face effect as much as adults. The reaction time data was also recorded for this study which confirmed that 6 year olds like 10-year-olds, and adults were slower to recognise composite faces. However, when the composite faces were inverted, younger children demonstrated no inversion effect and took the same amount of time processing upright faces. Consequently, the conclusion drawn was that although the accuracy performance of 6-year-olds tells us that they are as efficient as adults in holistic processing it is the speed of processing that differentiates the performance of children from adults. I will return to reaction times in face processing and speed of processing later in this chapter.

Mondloch, Pathman, Maurer, Le Grand and de Schonen, (2007) tested 6-year-olds for a composite face effect and reported a strong effect for unfamiliar faces was found, as children perceived the faces as a new face in the aligned condition, even though the top halves were identical and only the bottom halves differed. When the faces were misaligned accuracy improved remarkably and reaction times came down showing that 6 year olds could do holistic face processing. The conclusion was that by the age of 6 years holistic face processing is mature to adult level, but early development of holistic face processing is not sufficient to achieve adult level of expertise, may be a necessary prerequisite. Mondloch et al., (2007) referred to configural processing and claimed that perhaps for sensitivity to spatial relationship to develop and mature, holistic processing maturation is necessary; holistic processing may facilitate perception of configural information. Furthermore, De Heering, Houthuys, and Rossion, (2007) claimed that children as young as four are able to processes faces holistically which essentially means that additionally to holistic processing ability, something else is needed in order to achieve expertise.

So far it has been established that adults are face experts and this is so because they use holistic face processing (Tanaka and Farah, 1993) as well as configural face processing strategies (Friere et al., 2000) to perceive faces faster and more accurately. Infants on the other are able to discriminate their mother's face from strangers (Pascalis et al., 1995) from birth and in a matter of months they are able to discriminate between unfamiliar faces (Pascalis and de Schonen, 1994). At the age of seven months they posses certain ability to holistically process faces (Cashon and Cohen, 2001). In contrast, children have a very protracted development of FR where by they are better than infants but do not reach adult level till late adolescence (Chung and Thomson, 1995). However, children are able to use a holistic face processing strategy as well as adults from the age of 6. Holistic processing may be a necessary prerequisite for configural processing to mature to adult level but on its own it is not a sufficient strategy for face expertise to be at the same level as typical adult's ability to process unfamiliar faces (Mondloch et al., 2007).

2.8.4 Configural face processing

Another processing strategy mentioned in the adult face processing section that adults appear to have mastered configural processing.

Freire and Lee, (2001) demonstrated that children 4 to 7 years of age were better at recognising a face that differed from a distractor face in the shape of individual features than faces that differed in spacing between the features.

Mondloch et al., (2002) modified a single female face (called 'Jane') to create new versions (called 'sisters') – four that differed in the shape of internal features, four that differed in the spacing of the features and four that differed in the shape of the external contour of the face; and tested 6, 8 and 10 year olds. Six year olds were able to demonstrate a certain level of configural processing as their accuracy was above chance for the spacing set, which is in line with the rest of the literature as infants 7 months of age have limited ability to use configural processing (Cashon and Cohen, 2001). Nevertheless, development of configural processing lags behind featural and holistic face processing. The authors claimed that it is this delayed and prolonged development of configural processing that contributes to such a protracted development of face processing.

Mondloch, Geldart, Maurer and Le Grand, (2003) tested children on a battery of five tasks of matching faces for identity in order to investigate configural processing. Compared to adults 6 year olds made more errors on all the five tasks where as 10 year olds made more errors in only one of the tasks and this difference from adults was not due to a speed/accuracy trade off. Overall, the results of this study showed that development of configural processing is slow and perhaps causes poor performance. It should be noted that in Carey and Diamond, (1994) a reaction time difference was noted for the composite face effect, just as in Mondloch et al., (2003).

Lastly, blurred faces differing only in spatial information was presented to 8 year olds along side stimuli used in Mondloch et al., (2002) where stimuli were presented simultaneously for unlimited time (Mondloch, Dobson, Parsons, and Maurer, 2004). Participants were more accurate than when stimuli were presented sequentially and showed a larger inversion effect on the spacing set. This pattern of results indicates configural face processing, a pattern shown by 10-years-olds and adults in the previous study. One of the reasons for better configural face processing ability in this task was reasoned to be due to elimination of memory demands. Therefore, it appears that the actual paradigm used to test FR does have an impact on the results.

Configural face processing assumes that for FR to be as efficient as adult's perception of the spatial distance between features quickly and accurately is vital. Having ascertained that children as young as 4 can process faces holistically, and children as young as 6 can achieve adult levels of holistic processing, the assumption was that children may be poor at configural processing. On the whole studies have demonstrated that performance of children as young as 6 suffers because of poor perception of spatial distance between features and that 10-year-olds, although better than younger ones are not at the same level as adults. Once the featural information is removed by blurring, and memory demands lowered considerably, performance of 8 year olds improves considerably. The final inference being that perhaps poorer encoding efficiency and limited memory can partially account for young children's performance.

2.9 Models of face recognition

Models of face recognition and face processing have been proposed so as to explain the nature of the data in FR research, which in essence is that infants have the ability to discriminate face stimuli from birth, and that children as young as 4 to 6 have holistic and configural face processing ability nearly as good as that of an adult (De Heering et al., 2007; Mondloch et al., 2007; Mondloch et al., 2004). Adult level of expertise, however, is not achieved till late adolescence. I am going to briefly discuss three models proposed, but will not present evidence justifying any one of them.

2.9.1 Bruce and Young model (1986)

Bruce and Young, (1986) developed a classic model of FR in terms of processing pathways and modules for recognition of faces familiar to the individual. Seven types of information are apparently derived from face stimuli: pictorial, structural, visually derived information such as age and sex and identity information such as name, expression and facial speech.

The pictorial code corresponds to the 2nd information of the face and captures information about the light, grain and possible imperfections of a face as well as pose and facial expression. This module appears to facilitate FR in the studies where unfamiliar faces are presented first for learning and then same face along with a foil for recognition.

The structural code corresponds to the 3rd information of the face and captures information about the configuration of a specific face. This module discriminates familiar and unfamiliar faces i.e. faces that have not been previously viewed from various angles and with numerous facial expressions.

Bruce and Young's (1986) model treats facial expressions as an independent entity not essential for FR; a more abstract, and expression independent description of the face is then input to *Face Recognition Units* (FRU). So according to this model when a face stimulus is presented facial expression information is parsed out and a 'normalised' face is forwarded to FRU for FR. There is an assumption that identity and expression as independent processing whereby one is not dependent on another and that familiar and unfamiliar faces are processed differently.

This model made predictions such as processing of familiar faces should be automatic and rapid, while processing of unfamiliar faces should be effortful and time consuming. A second major prediction was that facial expression processing is independent of FR processing.

These predictions were tested and initially supported because recognition of familiar faces are quick and has been experimentally proved to be so; at the same time recognition of unfamiliar faces takes more time and again experimentally proved to be so (Posamentier and Abdi, 2003). However, since the proposal of the model numerous researchers have challenged both the predictions. I will not be covering the critical evaluation of the model in this thesis but use just one of the studies to demonstrate the type of challenge the model has since faced. For instance, Herba, Landau, Russell, Ecker and Phillips, (2006) demonstrated that facial expression has a significant impact on FR.

2.9.2 CONSPEC/CONLERN: A two process theory for infant FR

Morton and Johnson, (1991) proposed a two-process face processing mechanism to account for the discrepant data of newborns to 4 month old infants. This model has been highly influential and as such warrants a more detailed description than the previous one.

The discrepancy in question was that Maurer and Barrera, (1981) reported that 1-month-olds do not demonstrate preference for faces. Johnson, Dziurawiec, Bartrip and Morton, (1991) presented four stimuli (see figure 2.6) to 5, 10 and 19 week old infants.

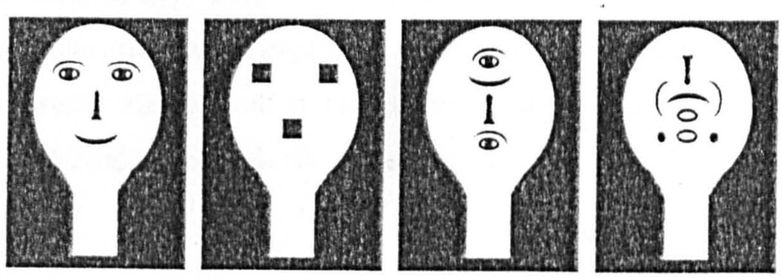


Figure2.6: Stimuli used by Johnson et al., (1991) in experiment 2. Reproduced from Morton and Johnson, (1991).

This time there was no significant difference in terms of head tracking to the four different stimuli, but mean looking time was significantly greater for schematic faces over linear and scrambled faces. In addition the mean looking time for schematic faces was greater than configurally matched faces, but failed to reach significance. For this reason, a final experiment was done and reported by Johnson, Dziurawiec, Bartrip and Morton, (1991).

The pilot studies found that 1-month-old infants tended to track most stimuli through 90° reaching a ceiling effect; hence, instead of moving the stimuli around, the infant was moved around the stimuli in a motorised chair. The study revealed that the mean angle at which 3- & 5-month-old infants disengaged from four stimuli did not differ significantly. In contrast, 1-month-old infants tracked schematic faces significantly further than any other stimulus. The authors provisionally concluded that a decline in preferential looking for schematic faces occurs sometime between 1 and 3 months of age. In order to ascertain this point of decline more precisely, further analysis was carried out, dividing the 1-month-old infants' data into two age groups: 'younger' (below 31 days) & 'older' (above 31 days). This revealed that only 'younger' infants demonstrated significantly greater tracking of schematic faces, now suggesting that the decline occurs between 4 and 6 weeks of age. It was concluded that the failure to find a face preference in previous studies (Maurer & Barrera, 1981) is likely to be a consequence of differing techniques.

Based on the findings of the three studies Johnson and Morton, (1991) proposed the structural hypothesis which in effect was the two process model. Firstly, there exists a device called 'CONSPEC' which contains innate structural information concerning visual characteristics of faces. This means information is available without requiring exposure to specific stimuli and it guides the newborns' preference for face like stimuli and is believed to be a sub-cortical structure.

Secondly, CONLERN function which is independent of CONSPEC acquires knowledge of human faces over the first two months and is a cortical structure. By the end of the first month CONSPEC has a weakened influence and the information about faces enters the cortical circuits more and more.

It has been suggested that the CONLERN system is 'set' by the CONSPEC mechanism which means it creates a bias towards faces which activates the cortical mechanisms thereby accounting for the ability at birth to track faces and the remarkable improvement in face discrimination observed at 2-3 months of age.

This model again has faced criticism on the grounds that it assumes that CONSPEC tracks face like stimuli and that faces are presented immediately after birth to trigger this system. Once again critical evaluation of the model is not considered in this thesis.

2.9.3 Experience- expectant and activity-dependent process of FR

Charles Nelson, (2001) proposed this model which is similar to the CONLERN system. However, what is assumed is that evolutionary pressures have led to a cortex that is flexible to learning during development so there are domain-relevant mechanisms that become domain-specific. In terms of FR all one needed to posit is

a. As species we experience regular exposure to face stimuli from birth onwards
b. Regions within the inferior temporal cortex have the potential to become specialised for face recognition
c. The face perception apparatus becomes tuned with exposure to faces which in turn leads to even more specialisation of those cortical areas and specification of neural tissue
d. This specification includes many types of information conveyed by faces such as facial expression, gender, age, eye gaze etc.

The crucial difference from Johnson and Morton model is this model assumes that like language there is a critical period within which experience is vital otherwise the impairment in FR development will occur. The role of experience in the development of expertise level face processing ability was also emphasised by Pascalis, de Haan and Nelson, (2002). The study presented 6 and 9 month-old-infants with human and monkey faces and reported that 6-month-old infants were better at discriminating monkey faces than 9-month-old infants. The conclusion was that human infants loose the ability to discriminate monkey faces due to lack of experience. Furthermore, Pascalis et al., (2005) sent infants home with monkey face pictures in order to familiarise the infants with these faces. The study reported that experience can influence the specificity of the face processing system. The results of this study indicated that infants who are given experience with monkey faces sustain the ability to discriminate monkey faces at 9-months of age. The other evidence comes from infants born with bilateral congenital cataract who were deprived of visual input for the first 7 weeks of life. These individuals, when tested as adults for a variety of face processing tasks, demonstrate the importance of visual experience for the normal development of specific aspects of face processing (Geldart, Mondloch, Maurer, de Schonen and Brent, 2002). In conclusion for the face processing mechanism to develop and finally reach adult level of expertise experience is essential at the critical period.

2.10 Conclusion

Adults are face 'experts' and can remember faces seen 35 years ago (Bahrick et al., 1975). Changing the orientation of a face impacts accuracy and reaction time performance, which has been explained using the 'encoding switch hypothesis' as well as 'single processing strategy'. Adults succumb to perceiving the face as a whole (Tanaka and Farah, 1993; Young et al., 1987; Carey and Diamond, 1994) and this facilitates performance. They also perceive distance between features very effectively and efficiently.

Infants can discriminate faces from a very early age especially the mother's face from outer face information (Pascalis et al., 1995). Although infants are adorned with such skills the development of FR is protracted and does not reach an adult level of efficiency until late adolescence (Chung and Thomson, 1995). Children as young as 4 years of age can use holistic face processing strategy and children 6 years of age acquire an adult level of expertise in holistic processing (Mondloch et al., 2007). In comparison, even children aged 8 years are not as good as adults in configural processing especially for speed (Mondloch et al., 2004). Thus, it has been speculated that holistic processing may have to fully develop and mature before configural processing matures.

The methodology used in FR research has an impact on the findings as has been demonstrated time and again (Mondloch et al., 2004; De Heering et al., 2007; Johnson et al., 1991).

Lastly, models of FR try to account the existing data and the experience-expectant theory along with CONSPEC and CONLERN hypothesis signifies the importance of learning in the critical period just like language development.

Chapter 3

Neural mechanisms underlying face recognition

Abstract

In this chapter I am going to first present evidence from neurophysiological research in favour of face specificity hypothesis. Then I present the human neural system model for the face perception and substantiate the development and existence of specialised neural systems for face processing with developmental data.

3.1 Introduction

Behavioural data presented in chapter 1 infers that adults are 'experts' in FR. The development of this expertise is protracted however, most typical adults gain the ability to perceive faces very efficiently and extract a variety of information from faces instantly. Does this reflect a specialised neural mechanism devoted exclusively to face processing (Johnson and Morton, 1991) popularly known as the *face specificity hypothesis* ? Or, does it reflect acquired visual expertise that, which is no different from expertise that can be acquired for other categories of complex stimuli (Gauthier, Skudlarski, Gore and Anderson, 2000), popularly known as *expertise hypothesis*?

Two of the three FR models presented in chapter1 emphasises the existence of specialised neural mechanism involved in face perception (Johnson and Morton, 1991; Nelson, 2001). The CONSPEC-CONLERN model (Johnson and Morton, 1991) makes a case for existence of innate face detecting system essentially subcortical circuits present from birth and the cortical neural system emerging gradually due to experience with the face stimuli (Johnson and Morton, 1991). The Experience-expectant activity-dependent model on the other hand underscores existence of domain-general neural circuits at birth. These get specialised over a long period of time into domain-specific circuits processing upright faces efficiently merely because of the prolonged experience and perceptual narrowing (Nelson, 2001). This particular view is supported by the finding that 6-month-old infants can discriminate human and monkey faces at an individual level while 9-month-old infants lose the ability to discriminate monkey faces at an individual level (Pascalis, de Haan and Nelson, 2002). This shows that discrimination ability of non-human face declines with time. Neuroscientists have endeavoured to find concrete evidence supporting or challenging the above models of FR. In the process not only have they found such evidences, but they have also proposed neural system models in order to explain the neurophysiological data (Haxby, Hoffman and Gobbini, 2000)

3.2 Evidence of specialised face processing region from brain damage patients

Bodamer (1947), first proposed existence of specialised neural mechanisms uniquely devoted to face processing, based on the findings that some patients were more impaired in face processing than object processing following brain damage. More recently Farah, Rabinowitz, Quinn and Liu (2000) reported a case study of 'Adam' who suffered brain damage as newborn and was tested at the age of 14 with a whole gamut of tests both for object and FR. It was reported that although his object recognition was far from perfect, it was considerably better than FR. The fact that FR ability in this individual was not supported by intact parts of the brain was direct evidence of localised FR area in the brain. Specifically, it suggested that even prior to any visual experience, humans are destined to carry out face and object recognition with differential neural substrates. This implied that anatomical localisation of the FR pathway is explicitly specified in the genome (Farah et al., 2000). Whatever role 'experience' played in the neural specialisation for FR the separate anatomical localisation for faces and objects do not require experience with the stimuli. This finding supports the CONSPEC system which claims that newborn infants have an innate subcortical neural pathway which predisposes them to detect face like stimuli in their visual field and naturally orient towards them. The experience-expectant model proposed by Nelson (2001), also gains support from this evidence to their claim of existence of a predisposition to naturally orient to faces.

Furthermore, Johnson (2005) asserts that research from blindsight or visual extinction due to brain damage demonstrated existence of separate routes for face detection and face identification. Face detection being supported by a subcortical route implicating superior colliculus, pulvinar and amygdala as the structures on this route and face identification, facial expression processing etc. being dealt with parvocellular channel to the cortical ventral visual stream. Secondly, anatomically neural pathway for lower spatial frequency (LSF) visual information is distinct from neural pathway for high spatial frequency (HSF) visual information. The subcortical pathway deals with LSF so LSF information from face stimulus is carried to superior colliculus and pulvinar via magnocellular channels and this route is insensitive to HSF. Vuilleumier et al., (2003) found that HSF which is important for identity of face activated fusiform gyrus and LSF face stimuli activated subcortical pathway. The parsimonious conclusion that can be finally drawn from the above is that face is a complex stimulus and requires both 'quick and dirty' processing by subcortical pathway as well as sustained response from cortical pathway. Perhaps, initially the pathways are acting independently then interacting followed by further independent actions by both pathways in order to fully process face stimuli.

3.3. Evidence of specialised face region from ERP and fMRI studies

3.3.1. Evidence of N170 from ERP and MEG in adults

With the advancement of technology, neuroscientists have used neuroimaging and neurophysiological techniques to investigate the uniqueness of face processing and the existence of specialised neural mechanism in healthy individuals. One such technique is electroencephalography, which records brain electrical potential (ERP) from the scalp. In adults, N170 which is a negative deflection, most prominent over the occipito-temporal scalp, peaks between 140 and 170 ms after stimulus onset and is face-sensitive (Bentin, Allison, Puce, Perez and McCarty, 1996). Sensitivity to the face means that latency is shorter and amplitude larger for upright faces compared to other class of stimuli such as hands, feet, trees, cars, buildings, dogs, inverted faces (Bentin et al., 1996; Puce, Allison, Gore and McCarthy 1995).

In contrast to claims of N170 being a specialised neural circuit for early face detections, some neurophysiological researchers have attempted to demonstrate evidence in favour of *expertise hypothesis*. In support of the *expertise hypothesis* firstly, Rossion et al., (2000) reported that N170 for inverted and scrambled face is also of larger amplitude and shorter latency; inferring that then it cannot be a specialised mechanism only to detect faces. Secondly, Gauthier et al., (2000) presented images of cars to car experts and bird images to bird experts while undergoing fMRI and reported that the fusiform gyrus selectively activated more for bird and car images in bird and car experts respectively. Here the claim was that these neural circuits are not exclusively dedicated to processing only face stimuli rather they will process any stimuli in which the individual has acquired expertise. Thirdly, Tanaka and Curran (2001) reported that N170 for birds and dogs was higher in experts than novices and reiterated the claims of *expertise hypothesis.*

In order to counter the above claim there has been numerous researches in favour of the *face specificity hypothesis*, only two of those studies are presented here to stress the point in favour of N170 and *face specificity hypothesis*. de Haan, Pascalis and Johnson (2002) presented adults upright and inverted human and monkey faces while recording ERP. The adult N170 showed specialisation to upright human faces and inverted human face did have increased amplitude and latency of N170 but not to monkey faces. The authors concluded that stimuli that are recognisable as a face but are not upright may engage both the face-sensitive regions and additional object processing regions, resulting in even larger amplitude to inverted human faces because of dual component contribution. The findings of Tanaka and Curran (2001) was questioned because the study had reported a slightly different location of 'object N170' i.e. more superiorly and posterior in comparison to 'face N170' (Xu, Liu and Kanwisher, 2005). Xu et al., (2005) tested car experts with car and human face images while undergoing magnetoncephalography (MEG) and examined the effects of visual expertise on face selective M170 (MEG), the response component that is same as N170 in ERP. The study found that cars did not elicit a higher M170 response in experts compared to novices. Furthermore, no correlation was found between the amplitude of M170 in response to cars and the level of behavioural expertise for cars. The M170 amplitude was correlated with successful face identification, but not successful car identification in car experts. Hence the inference has been that early face processing mechanisms marked by M170 are involved particularly in the identification of faces and not identification of objects in experts.

The N170, on the occipito-temporal scalp activates selectively at 170ms after stimulus onset for upright and inverted faces and not to cars, birds or monkey faces signifying that it is the location for dealing only face stimuli.

3.3.2. Evidence of FFA, STS, occipital, temporal and frontal from fMRI in adults

Exploiting functional Magnetic Resonance Imaging (fMRI) previous researchers accentuated the regions of fusiform gyrus as more active for face processing than object processing (Sergent, Ohta and MacDonald, 1992) or face processing that scrambled face processing (Puce, Allison, Gore and McCarthy, 1995). Activation of fusiform gyrus reaches highest level especially in the right hemisphere when participants are looking at faces and activation in this area decreases remarkably when participants are looking at houses (Haxby et al., 1999) landscapes or nonsense stimuli (Epstein and Kanwisher 1998). Kanwisher, McDermott and Chun (1997) tested 15 participants with photographs of face and common objects while undergoing an fMRI scan. They reported that a region in the fusiform gyrus responded significantly more strongly during passive viewing of faces than objects. Following this, numerous other tests for face selectivity was conducted while fMRI was being recorded. The results clearly indicated that the 'fusiform face' (FF) area responded to a variety of face stimuli, including front-view, grey-scale photos of faces, two-tone versions of the same faces and three-quarter-view grey-scale faces with hair concealed. This enabled Kanwisher et al., (1997) to conclude that activation of the region of interest i.e. the fusiform gyrus; did not reflect only general processing associated either with visual attention or with subordinate level classification of any random class of stimuli. This activation as they claimed was selectively involved in perception of faces and they named this area as Fusiform Face Area, popularly known as FFA.

The changeable elements of a face such as emotional expression and lip movements are processed by the posterior part of superior temporal sulcus (Hoffman and Haxby, 2000). Hoffman and Haxby (2000), in their ingenious experiment presented two faces with different eye gaze or identity in consecutive trial and asked participants to indicate if the presented faces had same eye gaze or same identity. In such a task the focus of the participants would be either on dynamic or static features of the face. Activity in the STS region was significantly higher when participants were paying attention to the changeable aspects of the face (See figure 3.2). The involvement of STS for dynamic facial feature has been qualified with the fact that various other regions such as the intraparitel sulcus (for attention); auditory cortex (for lip movement) and limbic system (for emotional expression) are all simultaneously activated for richer interpretation of such stimuli.

To this point in the chapter it has been established that N170 in adults is responsible for early detection of face. FFA activates significantly strongly for a variety of face stimuli such as front view, grey-scale photo, two-tone photos etc. (Kanswisher et al., 1997; Dekowska et al., 2008) and STS activates selectively for eye gaze (Hoffman and Haxby, 2000).

The other areas, such as the anterior part of the middle temporal gyrus (AMTG) and the orbitofrontal cortex (OFC) show high activity when famous faces or familiar faces are viewed (Sergent et al., 1992; Dekowska et al., 2008). Patients with epilepsy who have electrodes surgically implanted in the right ventrolateral prefrontal cortex have shown that this region is populated with very little clusters of neurons which respond vigorously to human faces (Dekowska et al., 2008). It has been pointed out that, because the volume of these structures is very small perhaps the PET and fMRI fail to pick it up.

The above evidence allowed face processing researchers to conclude with confidence that in adults a specialised neural system exists with specific neural network pathway for detecting face, eyes very early about 170 ms from the stimuli onset; followed by extensive processing of the stimuli in the FFA, STS, OFC, AMTG among other areas. Having presented the evidence favouring a neural system for FR, I now present the distributed human neural system model for face perception as proposed by Haxby, Hoffman and Gobbini (2000).

3.4. Model of distributed neural system for face perception

Haxby, Hoffman and Gobbini. (2000) proposed a distributed neural system model for face perception which has a hierarchical and branching structure and accomplishes the face perception task by coordination of multiple regions.

Haxby et al. – A neural system for face perception

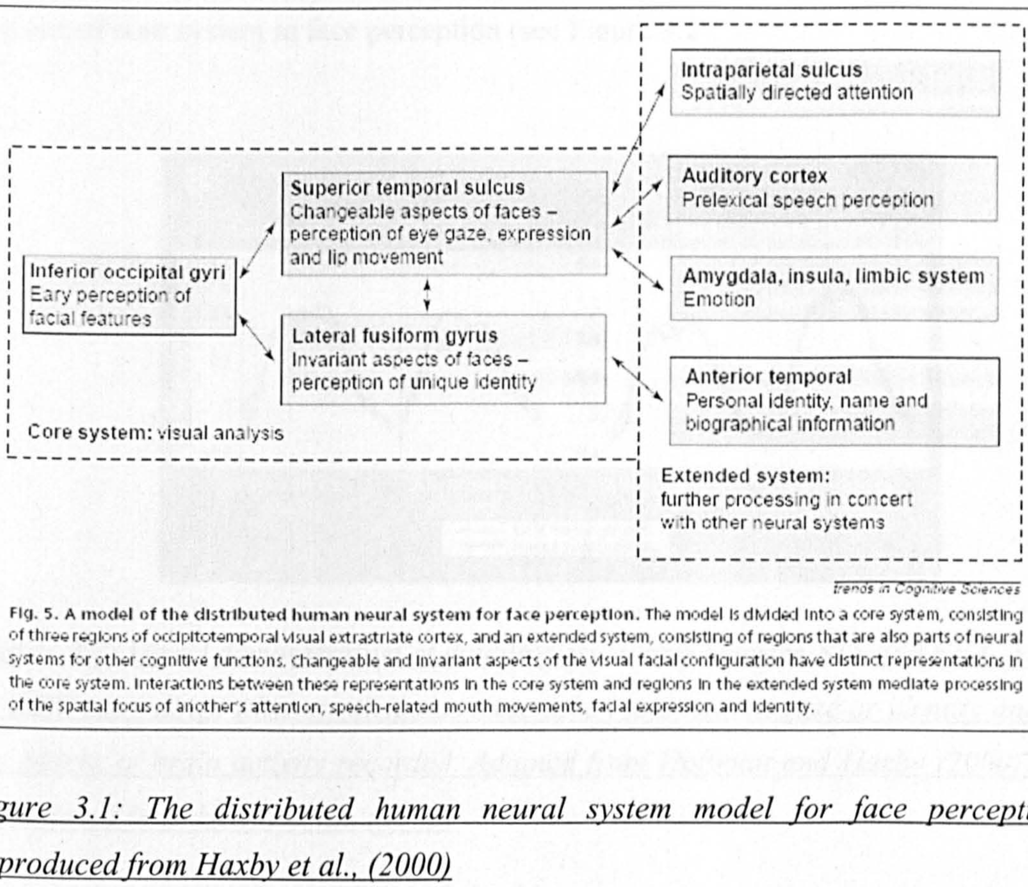


Fig. 5. A model of the distributed human neural system for face perception. The model is divided into a core system, consisting of three regions of occipitotemporal visual extrastriate cortex, and an extended system, consisting of regions that are also parts of neural systems for other cognitive functions. Changeable and invariant aspects of the visual facial configuration have distinct representations in the core system. Interactions between these representations in the core system and regions in the extended system mediate processing of the spatial focus of another's attention, speech-related mouth movements, facial expression and identity.

Figure 3.1: The distributed human neural system model for face perception. Reproduced from Haxby et al., (2000)

The model has a branching structure that emphasises a distinction between the representation of invariant aspects of faces, i.e. recognition of unique identity, called the *core system*; and the representation of changeable aspects of faces, i.e. the perception of information that facilitates social communication, called the *extended* *system*. The *core system* comprises three bilateral regions with an anatomical configuration that suggests a hierarchical organisation in which inferior occipital region may provide input to lateral fusiform gyrus and superior temporal sulcus (see Figure 3.1).

Hoffman and Haxby (2000) reported a neuroimaging study mentioned earlier and confirmed that the STS is more involved in the perception of facial movement and static images of changeable aspects of face, such as the expression, eye gaze direction and head orientation. On the other hand lateral fusiform gyrus has been shown to be more active when task of the experiment was identity. These results provided a direct demonstration of double dissociation between the functional roles played by these two regions of core system in face perception (see Figure 3.2).

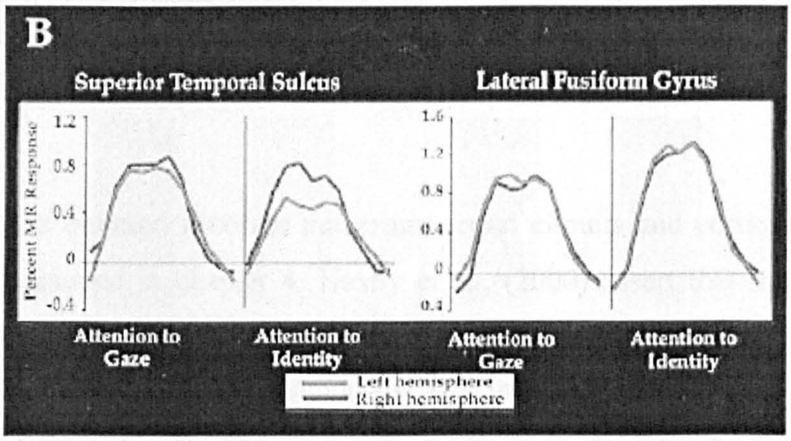


Figure 3.2: Direct demonstration of double dissociation between STS and FFA shown by fMRI recordings when participants were asked to attend to gaze or identity and 18 sec blocks of brain activity recorded. Adapted from Hoffman and Haxby (2000) and reproduced from Haxby et al., (2002).

According to this model, the neural systems for spatial attention and perception, is the intraparietal sulcus. Evolutionarily, both the eye gaze direction and head orientation is necessary to be perceived. Eye direction detectors (EDD) are more primitive and more ubiquitous than shared attention, perceived only by higher primates. It has been suggested that perhaps shared attention mechanisms have evolved to facilitate interactions in complex social groups and enable social learning (Baron-Cohen, 1995). There are connections between STS and intraparietal sulcus mediating and recruiting IPS when perceived gaze direction and head orientation is to be processed (Harries and Perrett, 1991).

Perception of speech related lip movement drawn from numerous neuroscience studies involves coordinated activity of visual region in STS associated with visual analysis of lip movement and auditory regions in the STS associated with analysis of phonemic content (Haxby et al., 2002).

Novel face leads to activation of lateral fusiform gyrus and inferior occipital gyrus (Hoffman and Haxby, 2000). A familiar face appears to involve a fixed sequence of stages that begins with activation in the temporal pole followed by activation in the anterior middle temporal gyrus resulting in retrieving name of the known person (Sergent et al., 1992).

The perception of emotion involves numerous neural circuits and cortical areas and these will be discussed in chapter 4. Haxby et al., (2000) assert that the degree of separation between functional roles played by different regions is not clear. For instance, fusiform gyrus may play a supportive role in interpreting expressions. At the heart of this model is the proposal that many face perception functions are accomplished by the coordinated participation of multiple regions. Furthermore, Haxby and colleagues have attempted to collate neurophysiological data from series of studies involved in investigating face processing, FR, facial expression perception, speech perception so as to back up every step of claim they make in their model (Haxby et al., 2002).

3.5. Developmental evidence of specialised face region from ERP and fMRI studies

It is established that adults have extensive neural systems dedicated specifically to processing faces. Evidence of a developmental pathway of neural mechanisms of face processing is launched with the aim to validate developmental models such as CONSPEC-CONLERN face recognition model.

Johnson (2005) asserts that in newborns the visual cortical area is relatively immature and compared to the cortical visual route the subcortical route structures seem to be more developed at the time of birth. The nasal and temporal visual fields feed differentially into the cortical and subcortical visual routes in humans. Anatomically it has been known that stimuli presented in the nasal visual field feed into the cortical route and stimuli presented in the temporal visual field feed into the subcortical route. Simion, Valenza, Umilta and Dalla Barba (1998) exploited this anatomical structure and presented face-like stimuli to newborns in either the nasal or the peripheral visual field. The study reported that face related preference was observed only when the face was presented in the temporal visual field, confirming the subcortical route to be more developed in newborns. These findings support existence of the innate mechanism as proposed by the CONSPEC-CONLERN model as well as existence of domain general processing proposed by the EXPERIENCE-EXPECTANT model of face processing.

3.5.1 Evidence from ERP of Nc, N290 and P400 in infants and N170 in children

The negative central (Nc) component, which is a negative deflection occurring between 400 and 800 ms after stimulus onset, is one of the most well-studied components of the infant cognitive visual ERP (de Haan et al., 2003). Nc has been interpreted as reflecting either infant's allocation of attention to more infrequently presented faces or to more unexpected face (Nelson, 1994). At six months Nc is of larger amplitude for mother's face than for a novel face (de Haan and Nelson, 1997). This recognition effect occurs only over the midline and right anterior temporal scalp regions and not the left or the posterior scalp regions, which is same as the adults.

de Haan and Nelson (1999), investigated if infants, like adults, show differences in spatial and temporal characteristics of brain activation during face and object recognition. 44, six month old infants were presented both familiar and unfamiliar faces and toys while recording ERP. The P400, a positive component most prominent over posterior lateral electrodes, peak at 450 to 390 ms from stimulus onset, for 3 to 6 month old infants was recorded. The P400 has been suggested to be a precursor to adult N170 because it has similar location on scalp (de Haan et al., 2002) and is faster for faces compared to objects (de Haan and Nelson, 1999). The Nc was larger for familiar than for unfamiliar and this effect interacted with the stimulus category; for faces the difference occurred at the midline and right anterior electrodes and for objects it was more widespread over midline and all temporal electrodes. This finding showed that the asymmetry observed was not due to mere familiarity but was unique to faces.

de Haan et al., (2002) emphasised that in order to draw any conclusions on existence of face expertise neural mechanisms, existence of N170 or precursors of N170 in infants, further investigation using both the inversion effect and species specific paradigm should be done. They presented upright and inverted human and monkey faces to adults and 6 month old infants. Adult N170 showed a unique response to upright human faces as mentioned earlier. The putative N170 in infants, P400 was larger for upright than for inverted faces but not species specific. It was thus concluded that perhaps certain face sensitivity exist from infancy and is spread beyond N170 i.e. involvement of P400; but experiences with human faces is definitely essential for the cortical specialisation to adult level. On the other hand, infants N290 was species specific but not orientation specific; differing from adults in that it peaked later than adults (290ms vs. 170ms) with smaller peak amplitude was smaller in comparison to adults.

Halit et al., (2003), investigated if either of the two face-sensitive infant components (N290 and P400) could be considered as developmental precursors of adult N170. They used the same paradigm as de Haan et al., (2002) and tested 3 and 12 month old infants and reported that at 12 months of age N290, like the adult N170 showed sensitivity to both species specific and orientation of face. The P400 also showed specificity to human faces and hence neither could have been ruled out as a precursor to the adult N170.

In conclusion so far, the N290 component is similar to N170 in that it shows an adult-like face inversion effect and a relatively similar timing and polarity. The P400 also has a shorter latency for faces and shows adult like inversion effect for 12-month-old infants. Overall, the findings suggested that both the N290 and P400 reflect processes that in adult may become integrated over time to form the N170 pathway. In other words, the structural encoding of faces may be spread out over a longer time of processing in infants than adults (de Haan et al., 2003). The speculation is, as this task becomes more automated, the processes involved in face processing are carried out quicker and/or in parallel rather than serial processing.

To this point ERP data has been presented for infants up to 12-month-old age, drawing home the point that although Nc, N290 and P400 all show selective activation to face stimulus, evidence in favour of N290 and P400 to be putative N170 in adults is more conclusive (de Haan et al., 2002).

At present there is a gap between studies with infant participants' up to 12 month of age and studies of older children i.e. 4 to 5 years old preventing a continuous charting of the developmental pathway for face processing.

Taylor, McCarthy, Saliba and Degiovanni (1999) were one of the first to test 4-year-olds for N170 using ERP technique. The N170 was at 270ms at 4 years of age and decreased steadily with increasing age and not reaching adult levels until teenage years. Further more, Taylor, Edmonds, McCarthy and Allison (2001), presented upright faces, inverted faces, eyes and scrambled faces to children aged 4 to 15 and reported that development of N170 for faces continued into adulthood whereas N170 for eyes matured at the age of 11. It was concluded that N170 follows a different maturational process for different classes of face stimuli. This finding was juxtaposed with behavioural data which claims that younger children use featural processing strategy more than configural processing (Mondloch et al., 2002) and the conclusion drawn was, this neurophysiological result is evidence for featural and configural processing and gradual switch from using one technique more to using the other technique more. The N170 latency and amplitude for eyes (featural processing) matured at the age of 11, whereas N170 latency and amplitude for upright faces (configural processing) continued to shorten in latency until adulthood (Taylor et al., 2001). In the same line it can also be claimed to be proof for Mondoloch et al., (2002) three step face processing because the first order processing not only exists at 4 years of age it exists at the 3 months of age (de Haan et al., 1999; Halit et al., 2004); however the holistic and second-order relational processing emerges gradually and continues to develop until adulthood.

3.5.2 Evidence from fMRI of FFA in children

Aylward et al., (2005) used fMRI and tested 8-14-year-olds, to investigate if there are any developmental changes to activation of fusiform gyrus when processing faces. fMRI was obtained while participants viewed faces and houses and a developmental change was observed. In younger children there was only activation of the inferior occipital gyri, whereas older children showed significant activation of bilateral fusiform gyrus in addition. Older children showed greater activation on the right than the left which was consistent with the adult data (Kanswisher et al, 1997), however this activation was not as robust as the adults. This could suggest that between12-14 years of age the fusiform gyrus is still not functioning at the adult level, which is consistent with the ERP data (Taylor et al., 2001) suggesting slower maturation. Weighing up this data with Haxby et al., (2000) model it was stressed that activation of inferior occipital gyri in both groups of children was consistent with the role of his region in processing the basic featural aspects of the face i.e. the core system. Only older children showed activation of the fusiform gyrus, the second level of the model, suggesting that older children are perhaps using a different strategy for face processing. Although precise conclusions cannot be drawn based on this evidence that fusiform gyrus is used for configural face processing; comparison with behavioural data (Carey and Diamond, 1977) allowed Aylward et al., (2005) to conclude that fusiform gyrus is not used for featural processing and in a limited way supported the multi-component model of face processing (Haxby et al., 2000) and the experience-expectant model (Nelson, 2001) of domain general gradually maturing to domain-specific.

3.6 Conclusion

The central debate in face processing has been the quest for existence of innate face processing neural mechanism devoted uniquely to human faces. At the same time the theories have attempted to propose the actual functioning of such systems through behavioural data. Data from prosopagnosia patients clearly indicates existence of a localised brain area specifically for face recognition (Farah et al., 2000).

The pathway for LSF and HSF described her highlights the hard work and precise coordination required by a multiple neural sub-systems in order to extract information from a face stimulus and a minor fault of a small element in this whole system can result in deficiencies in face processing. That perhaps is exactly the case of autism. In individuals with autism, research has clearly demonstrated that the entire face processing system is not malfunctioning resulting in complete face processing inability. Rather a minor 'default' in the aforementioned complex system leading to specific difficulty.

Simion et al., (1998), de Haan et al.,(1999), (2002), Halit et al., (2004) using the ERP method and visual field anatomical representation method, conclude that while specific areas and pathways are engaged in face processing from the first months of life, their response properties change continuously during first year. Although P400 and or N290 has been identified as precursor to adult N170 at no point did the infant ERP follow the same pattern as adults for face processing, emphasising the importance of prolonged experience for the adult like expertise to finally emerge (de Haan et al., 2002). Taylor et al., (2001) added to this notion by testing children aged 4 to 15 and demonstrating that developmental changes in N170 response to upright faces continues until the age of 15 years suggesting slow maturation. These lines of evidences are consistent with an 'interactive specialisation' perspective on human functional brain development in which the functionality of cortical regions arises as a result of interactions between brain regions, and between the whole brain and its environment (Johnson, 2000).

However, scientists such as Gauthier et al., (2000), Tanaka and Curran (2001), Rossion et al., (2000) have challenged such inferences, by demonstrating that the same fusiform areas can be preferentially activated by cars in car experts and by birds in bird experts. They suggested that visual experience is essential in differentiating individual members of a particular category and developing category-sensitive neural mechanism such that same cortical areas used for face processing may be deployed for the purposes of learning specific categories. Nonetheless, because adults are able to deploy fusiform gyri and acquire expertise in other fields it cannot be taken as sole indicator to negate the existence of face specific neural mechanisms. Gauthier et al., (2000) data only reinforces the importance of experience necessary to develop face expertise.

Chapter 4

Facial expression processing in adults and children

Abstract

This chapter to initially clarifies what is meant by basic and complex emotions in the literature and establishes the emotions and the FEs that will be considered in this thesis. Then behavioural studies on development of FE recognition are considered from infancy to adolescence. The data from infant research is included here in order to chart the developmental pathway of FE recognition. FE researchers have that there are certain factors which influence ones perception of FE. Some of these factors are considered here followed by limitations in methodology used to investigate FE processing.

4.1. Introduction

Facial expressions (FEs) are a crucial component of emotional and social behaviour and emotion recognition is crucial for subsequent social interaction and functioning. The ability to decode FEs is an important component of social interaction because of the significant role of facial information in appropriate modification of social behaviours (Herba and Phillips, 2004). For instance, happy facial expression (FE) successfully modifies the behaviour by reinforcing the action currently performed, sad FE modifies behaviour by aversion (Mineka and Cook, 1993) so on and so forth. So in a sense FE have been used as a tool for communication where information can be transmitted rapidly (Blair, 2003). This communicatory use of FE exists right from infancy and has been demonstrated by the social referencing research, where by an infant on discovering a novel object will look at primary caregiver and future behaviour of the infant will be determined by caregivers' emotional display (Klinner et al., 1983). The second suggestion is that FEs are tools to display current emotional experience (Darwin, 1872; Ekman, 1997). This assumes an automatic aspect of FE where the purpose is not communication, rather a by-product. The third suggestion comes from empirical evidence which shows that displaying emotion is nothing natural or automatic (Camras, 1985) it is overloaded with social and cultural values and *display rules.* From a very young age children learn what when and how to display, their emotions using FEs (Blair, 2003; Camras, 1985).

These are three of the many contrasting views that exist for FEs, illustrating the complexity of the social world especially in the case of FEs. Within this framework of FE as a tool for communication, as a tool of displaying the current emotional state and as a tool for following social norms I review FE recognition in children.

4.1.1 Communication loop for FE and emotion

There are three related processes in the FE and emotion communication loop which are as follows:

1. Individuals need to identify emotionally salient cues in their environment.
2. Identification of emotionally salient cues results in an internal affective state and as a response to the environmental cues there will be an emotional behaviour.
3. Before the emotional behaviour is finally displayed, the aforementioned internal affective state and emotional behaviour have to be regulated, possibly through inhibition of processes, or updating from past experiences, or following social norms.

The intact functioning of all of these three processes leads to appropriate behaviour within any social context (Herba and Phillips, 2004). All these three processes highlight the communicatory function of FEs, the emotional experience necessary and the social norms which dictate the display of FEs. For instance, fearful faces are seen as aversive unconditioned stimuli that convey information to others of the aversive nature of the stimuli (Mineka and Cook, 1993); so if fear is picked up as an environmental cue it should result in either a flight or fight reaction, assuming the person has a functioning social norm regulating mechanism.

The communication loop for FE tells us that emotional information can be obtained via a number of different domains; non-verbal cues i.e. FEs and body posture, verbal cues i.e. semantic information, prosody, context. Research has focussed more on identification of FEs as a paradigm for investigating emotion understanding because examining the development of emotional information via other domains is difficult due to confounding factors and barriers such as verbal ability (Herba and Phillips, 2004), scoring the data etc.

This thesis only considers emotional information transmitted via FEs and reviews the first of the three processes i.e. identification of emotionally salient cues namely FEs. This chapter summarizes the development of facial expression recognition in typically developing from infancy to adolescence.

4.2 Basic and complex emotion

4.2.1 Basic emotion

Paul Ekman through his seminal cross-cultural studies made the Darwinian idea of 'existence of basic emotion' concrete. Ekman and Friesen, (1971) presented posed Caucasian face images in places such as Japan, New Guinea, Borneo, Brazil and United states in order to determine if individuals from different cultures would assign similar emotional labels to faces with similar emotions. A remarkable 70-80 percent agreement was achieved for the six emotional expressions namely happy, sad, anger, fear, surprise and disgust irrespective of cultural, geographical, level of media exposure and literacy differences. This eventually led Ekman to label these emotions as 'basic' (Ekman, 1999); where as other emotions were said to be specific to certain cultures and the '*display rules*' of such cultures; hence not universal.

4.2.2 Complex emotions

Complex emotions unlike basic emotions require less automatic and greater cognitive component. It is this greater dependence on cognitive processes that gives these emotions the label of 'complex' (Griffiths, 2003). Damasio, (1995) viewed complex emotions as subtle variations of the basic emotions. For instance, panic has been argued to be variation of fear.

For the purpose of this thesis only the six 'basic' or 'universal' emotions and six basic FEs related to these emotions are considered.

4.3 Behavioural studies on development of FE recognition

The focus here will be on behavioural studies examining identification of FEs. The terms identification, recognition and perception have been used interchangeably in literature as well as in this thesis. The paradigms used to investigate identification of FEs require participants to sort, match, and label or describe FEs in the case of children. In the case of infants the paradigms used are obviously very different and tasks such as habituation or visual preference comparison tasks have been used.

4.3.1. Infant studies

One to two day old full-term infants are able to discriminate happy, sad and surprise when posed by live models (Field et al., 1983). Nelson and Horowitz, (1983) reported that 2 month old infants can discriminate happy from neutral face and three month infants can discriminate happy, sad and surprise expressions. There has been discussion in the literature that infants younger than 4 month old have very limited visual acuity in order to notice the subtle differences in FE. Hence the most parsimonious conclusion that can be drawn from infant studies testing infants younger than 4 month old is that these infants are capable of discriminating change in face on some dimension (Nelson, 1987). Nonetheless, it is a vital skill to be able to discriminate facial features without the knowledge of the meaning of various changes.

By 7 months of age, infants can recognise that different examples of the same expression belong to the same category (Nelson and Dolgin, 1985). This indicates that gradually by age of 7 months meaning of FEs are assimilated by infants. At 7 months infants are also able to generalise their discrimination between happy and surprise across the faces of six different models, irrespective of the order of presentation (Caron et al., 1982).

Having ascertained that infants can discriminate between various expressions the next step examined if infants notice the intensity of FEs. Kuchuk et al., (1986) reported that infants showed a differential patterns of preference for happy faces with increasing intensity. Nelson and Ludemann, (1987) reported a series of studies which examined the intensity discrimination in 4-7-month-old infants for various FEs. Firstly, the study concluded that 4-month-old infants can discriminate fear FE that varies in intensity and 7-month-olds can discriminate both fear and happy FE that vary in intensity. Secondly, the study found that by 7 month of age infants have generalised the discrimination in order to notice the varying intensity across different models for both happy and fear FE. So by the age of 7 months infants can discriminate between happy, fear and surprise FE and they can discriminate FEs of varying intensity.

At the end of their first year of life infants become capable of social referencing i.e. connect others FEs to environmental events and learn from them (Walker-Andrews, 1997). For example, twelve month olds were presented with a set of novel toys and the infants' mothers were directed to pose happy, fearful, or neutral facial expressions. Infants remained closer to their mothers when they posed fear, stayed at a middle distance for neutral, and moved towards the toys when they expressed happiness (Klinnert, 1984). In another study 12 month old infants were placed on a visual cliff at the shallow end and mother's at the other end, either posing happy or fear FE. All the infants were able to use the mother's FE to infer if it was safe to crawl across or not (Sorce et al., 1985). The social referencing studies indicate that from the age of 12 months infants can tell the difference between FEs and apparently modify their behaviour in accordance with the meaning of FE.

It should be noted here that due to absence of language, measures such as habituation and visual preference are generally used in infancy to examine FE recognition which is different to the paradigms used for older children. These methodological discrepancies have led researchers to question whether the same construct of emotion expression recognition is being measured over development (when language is present or absent), and the claim is that it is difficult to discuss continuity of these functions over development (McClure, 2000).

4.3.2. Developmental trajectory of FE perception from preschool years and above

Recognition of FE improves with age (Gross and Ballif, 1991); however the recognition does not just emerge at one particular age for all the six universal expressions (Camras and Allison, 1985). Children as young as two have the ability to sort faces showing FE (e.g. happiness) from faces showing physical states (e.g.

sleepiness) into separate groups (Russell and Bullock, 1985, 1986). This ability to recognise expression has been long found to be related both to age and the specific expression (Reichenbach and Masters, 1983); children recognise happy expressions earliest and with greatest accuracy followed by sad, then by anger, then surprise or fear (Gross and Ballif, 1991). Certain expressions are recognised more accurately and faster than others; for instance participants in Ireson and Shields, (1982) were able to discriminate happy expressions more accurately more often compared to any other expressions. Very little detail is required to recognise happy and sad FE as demonstrated by Walden and Field, (1982), where line drawings of happy and sad faces were effectively discriminated from surprise and angry faces. Widen and Russell, (2003) tested 3-5-year-olds on free labelling of basic FEs. Children's emotional expression labelling increased with age in a systematic order: 3-year-olds could label happy, angry, and sad expressions; 4-year-olds were also able to label fear, and 5-year-olds labelled surprise in addition to the former four. Recognition of disgust emerged later and was not consistently labelled by any of these age groups. Thus by the age of 5 years children are able to recognise FE of happy, sad and anger. Happy is claimed to be recognised with greatest accuracy (Camras and Allison, 1985; Gross and Ballif, 1991; Herba and Phillips, 2004).

In addition, it has been shown that younger children rely on FEs for information on another's emotional state to a greater extent than situational cues. Children's ability to identify emotions related to situations also increases with age. A study exploring facial expressions and situational cues of emotion demonstrated that children's reliance on situational cues increased with age. Methodology using emotion matching tasks demonstrated that preschool children could accurately match emotion of protagonists in familiar situation stories (Borke, 1971) and by the age of 5 children could describe situations which evoked basic emotions (Borke and Su, 1972). It was not until 7 years of age that children mastered describing complex emotions such as pride, shame and guilt (Harris et al., 1987). Another study reported that 3-5-year-olds focused almost exclusively on FEs, whereas by 9 years of age, children relied additionally upon situational cues (Hoffner & Badzinski, 1989). So by the age of 9 children are definitely able to appreciate emotion information from more than one source and are able to assimilate such information in order to regulate their behaviour.

Research has ascertained at what age a specific FE is noticeable to the child, for instance, as stated earlier children as young as 2 years old can sort happy FE. Actually it is even earlier than that happy FE can be reliably discriminated (Nelson and Dolgin, 1985). However, it is only by the age of 10 years, children can categorise FE at a level of accuracy comparable to that found in adults, and this developmental pattern is not uniform for all FE. Happy and sad are categorised better than fear and disgust (Camras and Allison, 1985). The developmental pattern of anger and surprise categorising is mixed; Gosselin, (1995) found anger categorisation the same as happy and sad whereas Camras and Allison, (1985) reported anger was harder than happy and sad but easier than disgust. It seems that anger FE may have very mixed outcome depending on the task.

FEs not only follow a differential pattern of development with ability to recognise a FE emerging at different stages of development, the time required to reach the adult expertise level is also variable. While happy is been relatively easy to recognise and develop expertise in, negative FE are hard for initial start of recognition and perhaps take a prolonged period to reach expertise level. Kolb et al., (1992) attempted to investigate at what age expertise is achieved to adult level for 6 FEs. Participants had to choose the FE that will best suit the face of the character in cartoon stories. Children 6-9 years of age were significantly different to the older groups in matching anger, sad, surprise and disgust and performance for sad and surprise continued to suffer till the age of 12 years. The FE for the cartoon task demonstrated the developmental trend, performance for happy was most accurate and achieved at the youngest age to adult levels, performance for sad, surprise and disgust continued to suffer till 13 years of age and disgust was the hardest to judge accurately. The authors concluded that a developmental shift happens between 6-8 years of age and again at the age of 14 years. When studies have used the wide array of FEs and tested a wide age range of participants then assertions can be made as regards competency. For instance, Widen and Russell (2003) claimed that at age of three children can label sad; however when that finding is juxtaposed against claims from Kolb et al., (1992) study it is clear that although a 3-year-old is able to label sad efficiency of such performance does not quite reach adult level till age of 13 years.

So far it has been established that FE recognition improves gradually and differentially for different FEs with happy being the easiest and disgust being hardest. Moreover, the task used to test the proficiency in FE must have some effect on the result as demonstrated above using categorising, matching and cartoon face task.

One of the factors essential in the developmental trend of FE is information on speed of processing. In real life FEs exist for very brief moments and change very rapidly imposing high demands on person's processing capacity. Slow speed of processing facial information may seriously hamper social communication and its development. FE research does not often include reaction time measures perhaps due to the nature of the paradigm or constraints of the design of the study. De Sonneville et al., (2002) investigated speed of processing FE in relation to age of participants. Children 7-10 years of age were tested on a series of task assessing matching, labelling and recognising FEs. Accuracy for recognising improved marginally but the speed of processing improved significantly from the 7-10 years of age, particularly for the negative FEs. Again speed of different FEs improved differently, happy being fastest most accurate followed by fear, angry and sad for speed. Furthermore, adult speed of processing was nearly twice as fast as that of children. This showed that when older children are tested perhaps reaction time is better measure of performance than accuracy. Moreover, in case of clinical population such as children with autism speed of processing is one of the factors leading to impairment in social interaction. This is discussed in more detail in following chapters.

Another way of exploring patterns of developmental change would be to use longitudinal studies, investigating continuity of individual differences. Brown and Dunn, (1996) did exactly that, testing children at 33 months of age, 40 months and then again at 6 years of age. A combination of observational (qualitative) and quantitative data was collected which among other findings reported that there was a remarkable stability of individual differences in children's understanding of emotions over a three year period. The children who at 3 years of age were better at identifying FE and linking FE to situations that provoke the expression were better at labelling and explaining complex emotions at the age of 6 years. This shows that developmentally if children are better in early years they retain this enhanced ability over the time period and are able to build on it.

We know that FE recognition skills develop over a prolonged period of time even though infants as young as 7-month-olds can reliably discriminate FEs. It has been established that methodology used to investigate FEs does have some impact on the findings and at later stage of childhood perhaps reaction time measures will contribute more to the progress of children than accuracy data. It has also been ascertained that individual differences exist in recognition of FE and this continues with reliable stability making children who are better to start with get even better with complex emotions in later life.

The effect of intensity of emotion on performance continues through the preschool and adolescent years. Children 4-15 years of age were tested with varying intensity of FEs, where intensity varied from 25 % to 100%,,for explicit FEs matching task. Children's accuracy improved with age for all FEs except anger. Accuracy improved with intensity and further analyses revealed that accuracy improved the most from 25% to higher intensities for fear and happy FE. Higher intensity was associated with more accuracy particularly for fear, disgust and happy. This result indicates that both expression intensity and emotion category impact on FE recognition (Herba et al., 2006).

4.4 Factors influencing FE perception

4.4.1 Gender differences

In general the review on gender differences highlight that the overall performance of boys and girls of similar age and verbal ability is not significantly different (Camras and Allison, 1985; Brody, 1985). However, Zahn-Waxler et al., (1984) and Hall, (1978) are the two reviewers who claimed that girls were better in FE recognition. In literature this difference exists mainly because of the studies included in specific reviews (Gross and Ballif, 1991)and the type of emotion stimuli used in those studies.

The doubt of sex difference on FE recognition was lifted by a meta-analysis. McClure, (2000) conducted a meta-analysis to examine sex differences in FE recognition and provided a clear evidence for a small, although robust female advantage over the developmental period from infancy to adolescent. The fact that sex effect was noticed at infancy allowed McClure, (2000) to assume that other factors associated with being female may play a role in development of FE recognition, meaning the differences may be related to difference in neural systems in males and females. Another probability speculated by Blair, (2003) and Herba and Phillips, (2004) is that the sex difference in upbringing and education may influence sex difference in FR. Socialisation and *display rules* are different for boys and girls and this is taught from a very early age eventually perhaps resulting in small but robust sex difference.

4.4.2 Facial features

The face is composed of facial features namely the eyes, forehead, nose, mouth and chin and changes in each of these components leads to a FE. It is the perception of individual features as well as the whole gestalt which leads to accurate discrimination of FE. Ekman and Friesen, (1971) classified the whole face into action units and it is the changes in these action units both individually and in various permutations and combination that results in both basic and complex emotions being expressed on our face as a FE. Cunningham and Odon, (1986) asserted that children gave more weight to certain facial features than others.

Analysis of misjudgements of FE highlighted a systemic pattern, extraneous facial features such as hair line, were never the reason for inaccuracy which meant that children only focussed on relevant facial features when perceiving FE. One of the reasons for misjudgement was, FEs which had similar eyes and/or mouth were found to be confusing. Angry faces have been known to be mismatched to faces having similar eyes i.e. disgust (Camras, 1980) and neutral faces misjudged as sad (Reichenbach and Masters, 1983). Reichenbach and Masters, (1983) found that providing situation information did not aid the decisions and similar pattern of misjudgement persisted regardless of age. Although in experimental conditions children are known to exhibit systemic errors, in real life social situations typically developing children indicated that they were able to effectively discriminate among various basic emotions (Gross and Ballif, 1991). It cannot be claimed with same assertion as sex difference that facial features have significant influence on FE perception.

4.4.3. Verbal ability and IQ

Children's verbal ability has a great influence on recognition of FE, depending on the response that is required under experimental conditions. When asked open ended questions girls made more errors in FE labelling task compared to when they were presented with forced choice questions (Ireson and shields, 1982). If the task requires an explanation and production of emotion labels then the recognition scores have been found to be lower than when only comprehension skills are tested. In the same way, if conflicting information was presented then the performance was dependent on verbal ability of the child (Reichenbach and Masters, 1983); lower verbal ability participants relying more on photograph and higher verbal ability participants relying more on the description of situation. Adaptations in research methods, such as providing both verbal and visual cues, may ameliorate some of the problems associated with verbal response from children.

It has been established that with increasing age, a wider range of social experiences, and accompanying changes in verbal ability, children are able to identify and explain both basic and complex emotions effectively (Gross and Ballif, 1991). In typically developing populations the relationship between IQ and development of FE has not been investigated, however in Williams Syndrome effects of IQ has been found to be related to emotion recognition (Gagliardi et al., 2003). IQ may affect children's performance on FE recognition task via different routes such as the ability to attend to numerous stimuli at the same time, verbal ability, ability to think abstractly, association of experience with the stimuli, speed of processing (Herba and Phillips, 2004). Studies investigating potential effects of IQ on FE perception throughout childhood and adolescence is required in order to draw concrete conclusions.

4.4.4. Socio economic status (SES)

There is a substantial body of evidence that children from families of deprived socio-economic background are significantly more at risk for emotional and behavioural difficulties in childhood (Goodyear, 2002). Most studies of FE recognition are conducted in schools and educational institutions existing in middle class areas so the effect of SES cannot be reliably inferred from this. Smith and Walden, (1998) tested Afro-American children from a very deprived area and reported the usual developmental trend with a twist. Children's accuracy for fear FE was very high and the suggestion was this was result of exposure to high-stress living environment. There is evidence of enhanced level of perception of anger in children who are physically abused (Pollack and Kistler, 2002). Taken together these results suggest environment in which children develop may bias them towards identification of specific expressions.

4.5 Limitations in methodology and validity of conclusions

Several characteristics of research in the field of FE have an effect on the external validity of the findings. The main sources of bias included are discussed below.

4.5.1 Quality of visual material

A number of studies testing preschool children used schematic or line drawing of FE. This may have been over simplistic, static and lack the richness of information that is available to individuals in natural setting and social environment. Furthermore, Gross and Ballif, (1991) argued that in real life individuals use more information than what can be provided in experimental conditions. Participants may be drawing on real life experiences to make the judgements in experimental conditions; resulting in incorrect response. Reviewers canvas for the use of standardised stimuli such as the Ekman and Friesen, (1976) faces to enable comparisons across studies resulting in valid conclusions (Herba and Phillips, 2004; Gross and Ballif, 1991). Use of dynamic stimuli is also highly regarded, as it would be closer to real life situations, and may trigger completely different neural structures compared to static faces (Haxby et al., 2002).

Preschool children generally are asked to sort or match the FE and the strategy used by participants for such tasks can be dependent on the type of stimuli used. Field and Walden, (1982) tested preschool children on FE matching task but used either line drawings or videos as stimuli that needed matching. The results in the two matching tasks were completely different bringing to light the fact that line drawing matching may be tapping into featural processing. One other factor influencing matching task results may be educational experiences. Preschool children taking part in research are generally children attending day care centres, playgroups etc. where a vital part of regular activity involves matching pictures, sorting etc. Thus practice effects may have impacted the validity of these studies (Gross and Ballif, 1991).

4.5.2 The response required from the participants

The response required from participants for FE has been varied from recognition, identification, perception, to description of actual emotion or labelling. Responses may rely differentially on verbal ability, visuo-spatial skills or other cognitive skills (Vicari et al., 2000). Language has a huge impact on the response required i.e. labelling of description of emotion places demands on participants' language ability whereas FE identity using sorting or matching entails very little use of language. Researchers testing preschool children try to eliminate language effects by using matching, pairing and sorting tasks but they may not be tapping in to the FE perceptual skill of the participant at all. In short there is a trade off in not only the stimuli used but the task demands associated with it.

Not many studies record speed of processing, mostly it is the accuracy scores taken into consideration. De Sonneville et al., (2002) reported a study where dynamic FE was used and the speed of response was also taken into account. The authors emphasised that FE change very rapidly in social situations and slow processing will seriously impede communication and social development. Their results indicated that speed of processing increases with age more so for the negative emotions. Studies such as these stress the importance of numerous variables assessing the development of subtle skills in FE processing, especially in case of older children.

4.5.3 Age range and distribution of the participants tested

The age of the participants tested has been vague at times, with description based on age or school years particular to the country of the researcher or other local definitions, the classic one being 'preschool children'. Literature scrutinising the developmental pathway would benefit from standard age descriptions.

4.6 Conclusion

Literature of FE research verified that a FE discrimination mechanism exists from infancy and gradually becomes faster and more accurate as the individual matures

(Herba and Phillips, 2004). The six basic FEs have a differential developmental trend both as far as time line of development is concerned as well as initial start up point. Happy is the first FE to be reliably discriminated from approximately the age of 4 months (Nelson and Horowitz, 1983) and perhaps requires the shortest time length to reach an adult level of expertise (Camras and Allison, 1985; Walden and Field, 1982). Disgust is the hardest FE to recognise and it is not until the age of 6-7 years that disgust is reliably recognised (Widen and Russell, 2003),with expertise level not reached until almost the age of 15 years (Kolb et al., 1992).

So from seven months of age happy is discriminated, from the age of 1 meanings of FEs are inferred and behaviours modified by infants, from the age of 3 labelling of FEs is achieved and from the age of 5 understanding of complex emotions emerges. However, adult-like expertise levels for negative emotions are not reached almost until the age of 15 years. When accuracy is achieved for a particular FEs such as happy at the age of 10 similar to adult level, even then speed of processing highlights room for further improvement (De Sonneville et al., 2002). Finally both intensity of an emotion and emotion category impacts on recognition results (Herba et al., 2006). Children who are better at FEs at the age of 3 continue to retain this superior ability over prolonged period of time and build on this. In other words, if a 3-year-old is good at FE recognition at the age of 6 the person will be better than their peers in their understanding of complex emotions, in picking up emotional cues from environment and modulating ones own behaviour accordingly.

Children gradually start to use situational cues to understand the nature of emotion as they get older and draw information both from FEs and situational cues (Borke, 1971). Understanding of complex emotions, as well as being aware of the dissociation between internal emotional state and display of emotion comes later in the childhood. However, the learning that in the social world one does not display the emotions felt at all times starts very early, and this display rules is likely to cause confounding effects in situation cues experiments (Reichenbach and Masters, 1983).

Methodology and stimuli used in the research has an effect on the findings, as do the characteristics of participants such as verbal ability, general intelligence, gender and SES. Life experience enhances a person's ability in recognising certain FEs more than others, for instance children subjected to physical abuse are more aware of fear FEs and fear emotion in their environment.

Due to lack of research with adolescents the final endpoint of maturation for each FEs is still not ascertained and the time line for each FEs is not known with certainty due to lack of focus on typically developing adolescents and their perception of FEs. On the other hand infant research has been more robust in their research and findings in FE as far as infants are concerned.

Chapter 5

Neural systems for facial expression processing

Abstract

The main aim of the thesis was to investigate FE production in the case of children with autism and investigating if the FE perception is atypical in the autism population. FE processing has been investigated both from behavioural and neurophysiological perspective and in order to consider FE in atypical population in its entirety it is vital to explore the findings of the neuroscientists as well. The findings of the research reported links with behavioural as well as neurophysiological theories of face processing. With this in mind I explore the neural system for FE recognition in this chapter both in case of adults and children without extensively covering all aspects of the complex system.

5.1 Introduction

Neuroscientists using imaging techniques have investigated the various aspects of face processing and clearly suggested a spatial and temporal dissociation in the processing of identity and emotion (Munte et al., 1998). Most studies investigating neural correlates for emotion processing used FE as the stimuli, Phan et al., (2002) conducted a meta-analysis of 55 PET and MRI studies on FE perception using FE as the stimuli and concluded that there is no one specific brain region consistently engaged in processing FE. Although, both cortical (prefrontal, frontal, orbito-frontal cortices, occipito-temporal junction, cingulate cortex) and sub-cortical regions (amygdale, basal ganglia and insula) have been claimed to be activated by different emotion stimuli (Damasio et al., 2000; Gorno-Tempini et al., 2001), the site of processing is not always constant. It is more a combination of various cortical and subcortical structures resulting in perception of FE.

5.2 The neural system for FE processing

Phillips et al., (2003) proposed the existence of two parallel neural systems for emotion processing which were as follows:

1. A system comprising subcortical and ventral frontal cortical regions important for the identification of the emotionally salient cues and generation of emotional states;
2. A system comprising dorsal frontal cortical regions important for the regulation of the subsequent behaviour as a result of identification of emotional cues.

This signifies importance of both the subcortical structure namely the amygdala and the cortical structures such as the orbitofrontal cortex (OFC), medial prefrontal cortex (MPFC), prefrontal cortex (PFC) and STS.

5.2.1 Evidence of subcortical and cortical activation and modulation

The speed of FE processing has been investigated using event-related functional MRI and N170 has been found to be sensitive to faces, being a reliable index of early stages of face processing. Batty and Taylor, (2003) presented a large number of unfamiliar faces with 6 basic expressions, plus neutral faces, to 26 young adults while recording event-related potentials. This was an implicit emotional task, which showed effects starting at the P1 component (94 ms) followed by N170 (140 to 220 ms). P1 has been implicated to be involved in global face processing; this study extended it to early processing of FE as well. The result of Batty and Taylor is consistent with Bruce and Young, (1986) both claiming early automatic encoding of FE alongside other face information encoding. Thus FE are detected and processed very rapidly approximately 94 ms after stimuli onset and automatically. The N170 for positive and negative faces were of different latency i.e. negative faces had longer latency. This appears to be counter-intuitive but Batty and Taylor, (2003) reasoned that the subcortical pathway is activated by negative emotions and rapidly sends information to different levels of ventral pathway resulting in the N170 being activated later. Moreover, N170 for fear is larger and this substantiates the subcortical feedback loop.

Taken together it can be concluded that both the subcortical and the cortical neural system activate when FEs are presented for identification. Depending on the FE, the feedback loop to the cortical neural system is different thus affecting the speed of processing of different FE.

5.2.2 Evidence of amygdala activation in adults

The amygdala, a subcortical structure, has been consistently implicated with FE processing, particularly activating in response to fear emotion and FE. (Adolphs, 2001; Blair et al., 1999; Morris, et al., 1998; Vuilleumier et al., 2001).

Studies of patients with brain damage and animal research have long established that limbic structures, such as the amygdala, play a vital role in processing biologically significant stimuli, especially fear FEs. Amygdala lesions in humans, have consistently been associated with impairment in fear expression recognition (Adolphs, 1999; Calder et al., 1999), in 50% of cases, with impairment in recognition of sad expression (Fine and Blair, 2000); but rarely cause impairment in recognition of happy (Fine and Blair, 2000).

Evidence of the sub-cortical pathway activation in response to FE stimuli of fear was demonstrated by Morris et al., (1998). Using PET the cerebral blood flow to the amygdala, the superior colliculus and the pulvinar was reported to increase in response to facial expressions of fear. It has been claimed that fear, sad and happy expressions all modulate amygdala activity (Morris et al., 1996; Phillips et al., 1997).

Morris et al., (1998) draw attention to the fact that anatomically, the amygdala receives sensory input from the pulvinar and the medial geniculate nucleus and highly processed sensory input from the anterior temporal lobe. The output of the amygdala is projected to the temporal cortex and to earlier visual areas in the occipital lobe and also to OFC. With this knowledge Morris et al., (1998), embarked to investigate brain activation patterns in the regions of interest while participants were watching fear FE of varying intensity. The pattern of activation on closer analysis revealed that the left amygdala had enhanced responses to fear faces relative to happy and responded to increases in intensity of fear. The left amygdala also responded to decreases in intensity of happy. This was taken as indication that the left amygdala in particular is not merely involved in mediating response to fear and/or threat in the environment but is more complex than that. The right amygdala does not respond to any intensity of fear expression. Although other studies have argued the case of right hemisphere dominance for face processing tasks, the findings of Morris et al., (1998) signified that facial emotion processing is much more complex than a simplistic right hemisphere dominance model. It has been professed that the nature of a task may be crucial in determining the extent to which each hemisphere is engaged.

The case of double dissociation between right and left amygdala (essentially right and left medial temporal lobe) has also been successfully verified by Funayama et al., (2001). This study examined the role of the amygdala in modulation of behavioural fear response, both in a picture viewing paradigm and instructed fear paradigm; by testing healthy participants, right temporal lobectomy (RTL) and left temporal lobectomy (LTL) patients. A clear double dissociation was displayed in the findings where by LTL patients showed an increase in startle during a picture viewing task and RTL patients showed an increase in startle during an instructed fear task. The conclusion was that right amygdala modulates behavioural response when a picture stimuli with verbal instruction are presented. Likewise, left amygdala modulates behavioural response only when the instruction of threat is associated with innocuous stimuli.

It is well established that the amygdala is involved in the processing of fear FE as well as discriminating FE at the very initial stage of processing and modulating the activation pattern of cortical neural pathway (Leppänen and Nelson, 2009).

5.2.3 Evidence of STS and OFC in adults

The cortical pathway for FE processing among other areas involves the STS initially, as reported by Haxby et al., (2000). The posterior STS region is implicated with processing dynamic FE (Hoffman and Haxby, 2000) and inferring intentions of people from FE (Pelhprey, Morris and McCarthy, 2004). The earliest activity that discriminates between FE in the frontal lobe is seen in the midline occipital cortex from 80 to 110ms after stimulus onset (Halgren, Raij, Marinkovic, Jousmaki, and Hari, 2000) as recorded using ERP. This is followed by activation of fusiform gyrus at approximately 160ms.

The orbitofrontal cortex has also been implicated in the recognition of FEs in top-down modulation of perceptual processing (Damasio et al., 1994).

5.2.4 Evidence of other areas processing FE in adults

Disgust expressions engage insula and putamen (Phillips et al., 1997) and insula damage results in failure to recognise disgust expressions (Calder et al., 1999).

Anger expressions are asserted to curtail behaviour of others by response reversal (Blair et al., 1999) and the orbitofrontal cortex is crucially implicated in response reversal. Activation of the orbito frontal cortex has been reported in response to anger expressions (Blair et al., 1999) and no amygdala activation for anger has been reported in the literature.

It has been illustrated here using neurophysiological data and evidence from brain damaged patients that the amygdala is vital for fear perception. It has also been showed that the left and right amygdala activate differently to varying intensity of fear and other FEs and to different types of stimuli such as picture images or story context. The frontal cortex (namely the PFC, OFC, MPFC) activates in conjunction with subcortical structures and is modulated, as well as modulates, structures such as the amygdala, insula etc. Hence it appears, frontal cortex is more involved in the second level of the parallel neural system of Phillips et al., (2003) whereas subcortical structures influence the level one more.

5.3 The ontogeny of FE processing

Prior to verbal communication infants rely on communication via the non-verbal channel which primarily is reading others' FEs. It is vitally important for infants to derive information regarding primary care givers' mood, feelings and intentions as well as to learn continuously about the environment. When infant becomes mobile, the FE of the mother is used to derive information regarding the safety of the physical environment (Klinnert, 1984). Thus, accurate decoding of FE is absolutely fundamental in early interpersonal communication, learning and developing and above all effective survival for each individual right from birth. Literature corroborates that the adult emotion processing neural network discussed above emerges early in postnatal life; with the subcortical brain systems (essentially the amygdala) being functional at birth and orienting infants' attention towards faces and gradually enhancing cortical activity of specific areas in response to face stimuli (Johnson, 2005). Reciprocal connections between visual representation areas and the amygdala as well as the orbitofrontal cortex have been observed soon after birth in macaque monkeys and both structures seem to reach anatomical maturity relatively early in development (Machado et al., 2003). Amygdala lesions in neonate monkeys result in abnormal affiliation and fear-related behaviours, possibly due to the underlying impairments in evaluation and discrimination of safe and potentially threatening physical and social stimuli (Bauman et al., 2004). Neurogenesis of the amygdala in monkeys completes by birth (Humphrey et al., 1968) but the subcortical pathway in healthy human newborns cannot be researched for ethical reasons and any conclusions drawn based on animal research must be tentative. Humans are the only species with a prolonged nurturing, developing, learning and caring period that lasts for more than a decade. This means, unlike monkey's brain and neural circuits, the human brain undergoes a prolonged maturation involving myelination of the axons; connections among various brain regions continuing to develop finally resulting in a more refined wiring pattern.

It is unlikely that infants can visually discriminate internal features at birth and in the first couple of months of life (Nelson, 1987). Reliable perception of FEs (i.e. attention to configural information in face and the ability to recognise FE across variations in identity and intensity) has been demonstrated not to exist substantially until 5-7 months of age (Nelson and Dolgin, 1985). From the time of birth infants rely more on multimodal cues such as audio cues to decipher social communication information and only later acquire representation discriminating unimodal information. Flom and Bharick, (2007) presented 4-7-month-old infants with happy FEs for a visual-paired tasks and then paired habituated faces with novel fear or angry faces. Only from 7 months of age were infants able to effectively discriminate unimodal stimuli of happy faces from fear or angry faces; with unimodal auditory discrimination ability appearing at 5 months of age.

5.3.1 Evidence of amygdala activation in children

Halit et al., (2003) reported a positive ERP component approximately 400 ms after stimulus onset over the medial occipital temporal scalp, which is larger for fear face compared to neutral FE in 7-month-old infants. This has been taken as a evidence of modulatory influence of the amygdala on cortical processing in infants.

Infants' reactions towards FEs are further biased by eye gaze directions i.e. if a fear face gazes at a novel object it induces an increase of the Nc that is more pronounced than if the gaze is directed at the infant (Leppanen and Nelson, 2009). As mentioned previously, subcortical activation cannot be tested in infants because of ethical reasons but the activation of occipito-temporal regions at such short latency has been taken as evidence of amygdala activation and of a modulatory effect, especially on the attention networks of the cortical face sensitive neural network.

For practical reasons fMRI is hard to administer with babies as they would not be still enough. Thomas et al., (2001) studied amygdala activation to fearful faces in group of children (mean age 11 years) and adults. Adults showed greater amygdalar activation consistent with previous research, on the contrary children showed greater activation to neutral faces. It was concluded that children perhaps find neutral faces more ambiguous resulting in increased activity of amygdala, which is consistent with behavioural data.

Killgore et al., (2001) studied developmental changes in amygdala in children and adolescents and reported that although the left amygdala responded to fearful faces in all children, this activity decreased in female adolescents but not in males. Females also had greater activation of the dorsolateral prefrontal cortex over that same period; whereas males showed an opposite pattern. This was interpreted by the authors as an association between cerebral maturation and regulation of emotional behaviour i.e. cerebral maturity eventually leads to suppression of amygdala activation.

These studies signify that although the subcortical route is functional from birth, it might take a long time to mature behaviourally and there may be significant gender difference in the developmental phase.

5.3.2 Evidence of cortical activation in children

Fear enhances activity in cortical attention networks from the age of about 7 months. Nelson and de Haan, (1996) found that the negative central (NC) component of infant ERP was of larger amplitude in response to fear faces compared to happy faces, highlighting a greater allocation of attention neural networks for fear facial expressions. However, it is difficult to draw conclusions by parallel comparison of adult and infant FE research which use completely different paradigms and different task demands. Hence Leppanen, Moulson, Vogel-Farley and Nelson, (2007) recorded ERPs to fearful, happy and neutral faces in adults and 7 month old infants under equivalent viewing conditions. Adults, like previous research, showed augmented amplitude of N170 for fear faces compared to neutral or happy face. In infants, significantly larger positive amplitude at inferior semi-medial occipito-temporal region, 380 ms after stimulus onset were recorded for fear faces compared to neutral and happy face. The attentional network NC was also larger for fearful face which was in line with the studies' behavioural task, where infants had longer looking time for fear. Together, these findings were concluded to suggest that cortical processing for different facial expressions in 7-month-olds varied, just like adults, and both face perception and attention-grabbing networks function in the first year of life.

Facial expression research in the field of neuroscience is inconclusive after the first year of life in humans. The neural network for FE has not been investigated for children between 1 to 4 years of age the ontogeny is imprecise. In their seminal study, Batty and Taylor, (2006) tested children aged 4 to 15 year olds with six universal expressions as well as neutral FE while ERP was being recorded. P1 was reported to be sensitive to configural changes across childhood and was a large, easy measure peak in children. P1 also showed marked changes in amplitude and latency with increasing age, hence P1 was recorded and changes noted in this study. P1 latency was sensitive to emotions in the young children in this early component. Fear had longer latencies that happy and surprised while happy had shorter latency than fear, disgust and sad. The P1 effect (120 ms for 4 to 7 year olds) was driven entirely by the two youngest age groups who use very early processing to detect emotions, suggesting that young children use this mechanism for early perception of certain emotions. This effect disappears with age, in parallel with age-related decreases in P1 latency and amplitude. The effects on N170 amplitude were only seen in 14 to 15 year olds. This double dissociation due to age indicates that the processing of emotions is not static and the neural mechanism changes with maturation. The N170 comes online for configural processing much later and indication is that until that happens other areas, such as P1, are executed for inferring information from facial expressions.

5.4 Conclusion

The amygdala as a subcortical structure has been ascertained without any doubt to be vital for FE processing. Animal studies as well as brain damage patients have long been testimony to the impact the amygdala or temporal lobe lesions can have on the individual's social life (Damasio et al., 1994). Although the left and right amygdala activate differently, it is still very early to define the neural pathway for every single variation of emotion and the influence of amygdala on its processing with any conviction. All that can be said at this stage is that both the subcortical and cortical pathway are equally important for FE processing. The subcortical pathway may do the 'quick and dirty' processing however, the OFC, PFC and MPFC have to analyse the information based on past experience, compute reward value make decisions, execute goal directed output. Both of these systems, as highlighted in the Haxby et al., (2000) model, have to work together continuously in a feedforward and feedback mechanism. Furthermore, it has been reported that subcortical neural system for FE processing exist from birth and is online from birth onwards more effectively than the cortical network initially. However, both the subcortical and cortical neural network takes a long time to mature and reach adult level.

Chapter 6

What is autism? Face recognition and facial expression recognition in autism population and participant selection criteria

Abstract

In this chapter I summarize several aspects of autism. I will first describe the diagnosis of the syndrome, then will present some theories of autism, such as the weak central coherence, social motivation hypothesis and the amygdala theory Considering the communication aspect of autism, I will focus on the face processing and facial expression processing. I will review the literature both from behavioural and neurophysiological perspective. The final section of the chapter discusses the types of participants involved in autism research in general and the participants involved in this particular research.

6.1 Introduction

Childhood autism is sometimes referred to as early infantile autism, childhood autism or Kanner's autism (DSM-IV). Manifestation of the disorder varies greatly depending on the developmental level and chronological age of the individual.

Leo Kanner in 1948 reported 11 case studies, 8 boys and 3 girls who were closely followed since 1938. These children presented with 'fascinating peculiarities' as reported by Kanner. He highlighted in each of these cases; intense interest with objects but minimal interest in people, repetitive patterns of behaviour, and an acute interest in specific field or objects combined with language difficulties. The outstanding fundamental disorder was the inability of these children to relate to people and situations right from birth. Parents in these case studies repeatedly highlighted that their child was 'self-sufficient', 'happiest when left alone' or 'perfectly oblivious to everything about them'. Kanner described this as an 'extreme autistic aloneness' that shuts out everything that comes to the child from outside.

Attention was drawn to language difficulties by highlighting the excellent rote memory, delayed echolalia, general language delay and confusion with personal pronouns. Most importantly, the communicative function of language was reported to be impaired in the sense that children failed to use language in social contexts. They also took language in the literal sense and Kanner reported this deficiency extensively in the case studies signifying the level of difficulty for the child and parents. Children also were reported to insist on sameness almost to an obsessive level leading to great distress to the child and as a result parents followed routines and rituals with great rigidity. Finally, Kanner, (1948) concluded that these children have come with the innate inability to form affective contact with people eventually manifesting in to "inborn autistic disturbances or affective contact".

6.2 Diagnosis of autism

6.2.1 DSM-IV (APA, 1994) diagnostic criteria:

DSM-IV specifies that the essential features of Autistic disorder are the presence of impaired development in social interaction and communication with restricted repertoire of activity and interest.

Criteria A1 list all the possible repertoire a child with autism may have that result in impairment of reciprocal social interaction which will be gross and sustained. The criteria includes impairment in eye to eye gaze, facial expressions, body posture to failure in peer relationship development at different developmental level, to lack of spontaneous sharing of enjoyment, to showing/taking comfort in their own company.

Criteria A2 list all the possible difficulties in communication both in the fields of nonverbal and verbal skills. The criteria highlights that there may be lack of language development to start with or individuals who do speak may have marked impairment in their ability to initiate or sustain conversation. The voice intonation, pitch, rhythm, rate or stress may be abnormal and there may be repetitive use of language and stereotypical or idiosyncratic language. Individuals may use neologisms or words and phrases. Finally this criterion warns clinicians to look out for lack of spontaneous make-belief play or social imitative play typical of developmental level. Children with autism are often seen not to engage in any imaginative social play such as play kitchen, or garage and tend to use these toys in a very mechanical way.

The final criteria A3 cover repetitive behaviour or restricted interests detailing the narrow interests of individuals which become a preoccupation with abnormal intensity or focus. It underscores the inflexible adherence to specific, non-functional routines and rituals. It has been accentuated that children with autism tend to insist on sameness and show resistance to change or are distressed with trivial change to routine. It warns clinicians to look out for repetitive motor mannerisms such as hand clapping, clicking or finger flicking; or whole body such as rocking, dipping and swaying.

The diagnosis of autism is reached if there is delay or abnormal functioning in at least one of the areas i.e. social interaction, language used in social communication or symbolic or imaginative play prior to three years of age. In most cases there is no period of unequivocal normal development but in some cases parents report a case of normal development until 1-2 years of age and then a difference noticed. If normal development is reported then according to DSM-IV (APA, 1994) this must not be beyond the age of three.

DSM-IV (APA, 1994) concludes with the note that children with autism, in most cases, have associated diagnoses of mental retardation that can be mild to profound. Individuals may display a range of behaviour from hyperactivity, short attention span, impulsivity, aggressive behaviour, hypersensitive to loud noise, touch or odour. Atypical natures in food habits, sleep patterns and emotions have all been reported.

6.2.2 ICD-10: DCR-10(WHO, 1998) diagnostic criteria for childhood autism

ICD-10 diagnostic criteria for research 10 (DCR-10) (WHO, 1998), classifies a group of disorders 'disorders of psychological development', that have (a) onset during infancy or childhood; (b) impairment or delay in development of functions that are strongly related to maturation of central nervous system; and (c) a steady course without remission or relapses. Childhood autism is one such disorder grouped under 'disorders of psychological development'.

Childhood autism is defined as a type of pervasive developmental disorder that has (a) presence of abnormal or impaired development that is manifest before the age of 3 years and (b) the characteristic type of abnormal functioning in all the following three areas – reciprocal social interaction, communication and restricted, stereotyped, repetitive behaviour. Other non-specific problems may co-exist such as phobias, sleeping and eating disturbances, temper tantrums and self directed aggression.

ICD-10 specifies the diagnostic criteria more concisely in comparison to DSM-IV and the following must be satisfied

A. Abnormal or impaired development is evident before the age of 3 years in at least one of the following areas
    1. receptive or expressive language as used in social communication
    2. development of selective social attachments or of reciprocal social interaction
    3. functional or symbolic play
B. A total of at least six symptoms from (1), (2) and (3) must be present, with at least two from (1) and at least (1) from each of (2) and (3)
    1. qualitative abnormalities in reciprocal social interaction are manifest in at least two of the following areas:
        (a) failure adequately to use eye-to-eye gaze, facial expression, body posture and gesture to regulate social interaction;
        (b) failure to develop (in a manner appropriate to mental age, and despite ample opportunities) peer relationships that involve mutual sharing of interests, activities, and emotions;
        (c) lack of socio-emotional reciprocity, as shown by an impaired or deviant response to other people's emotions; or lack of modulation of behaviour according to social context or a weak integration of social, emotional and communicative behaviours;
        (d) lack of spontaneous seeking to share enjoyment, interests or achievements with other people (e.g. a lack of showing, bringing or pointing out to other people objects of interests to the individual).

2. Qualitative abnormalities in communication are manifest in at least one of the following areas:
   (a) a delay in, a total lack of, development of spoken language that is not accompanied by an attempt to compensate through the use of gesture or mime as an alternative mode of communication (often preceded by a lack of communicative babbling);
   (b) relative failure to initiate or sustain conversational interchange (at whatever level of language skills are present), in which there is reciprocal responsiveness to the communications of the other person;
   (c) stereotyped and repetitive use of language or idiosyncratic use of words or phrases;
   (d) lack of varied spontaneous make believe or (when young) social imaginative play.

3. Restricted, repetitive and stereotyped patterns of behaviour, interests and activities are manifest in at least one of the following areas:
   (a) an encompassing preoccupation with one or more stereotyped and restricted patterns of interest that are abnormal in content or focus; or one or more interests that are abnormal in their intensity and circumscribed nature, though not in their content or focus.
   (b) Apparently compulsive adherence to specific, non-functional routines or rituals;
   (c) Stereotyped and repetitive motor mannerisms that involve either hand or finger flapping or twisting, or complex whole-body movements;
   (d) Preoccupations with part-objects or non-functional elements of play materials (such as their odour, the feel of their surface, or the noise or vibration that they generate);

Thus, according to the diagnostic criteria, it is clear that this is a social neurodevelopmental disorder that is evident by the age of 3. Diagnosis is possible from the age of 3 although clinical researchers are attempting to develop tools for early diagnosis. One of the prime reasons for early diagnosis is early intervention, as it is obvious from clinical research literature that prognosis in case of autism with no learning difficulties is very good. These criteria are for diagnosis for research purposes which clinicians do not have to follow stringently. Diagnosis for clinical purposes can be made on the basis of overall judgement of the clinician who has knowledge and experience of ICD-10, from interview encompassing history both personal and family and observation of the person at the clinic.

6.2.3 Autism Diagnostic Interview – Revised (ADI-R)

The ADI-R, a semi-structured, investigator based interview for caregivers of children and adults for whom autism of pervasive developmental disorders is a possible diagnosis (Lord, Rutter and Le Couteur, 1994). This revised interview has been reorganised, shortened and modified to be appropriate for children with mental ages from about 18 months into adulthood. The ADI-R is linked closely to ICD-10 and DSM-IV criteria; because although it was originally designed for research purposes only, it has been used more and more for clinical diagnosis (Lord et al. 1994).

ADI-R consists of 93 individual questions divided into 5 main sections
Opening sections
Questions on communication (both early and current)
Questions on social development and play (both early and current)
Questions about repetitive and restricted behaviours (both current and ever judgements)
A reduced number of questions concerning general behaviour problems.

The ADI-R enables better discrimination between non-autism children with severe learning difficulty and children with autism. This is because the ADI-R uses focussed descriptions of contexts on how non-autism children behave that is consistent through early development. The questions in each section and the detailed prompts incorporated enable the interviewer to gather information from the caregivers that is vital in highlighting characteristics of autism. The interview focuses on the caregiver's descriptions of actual behaviour as it has occurred in the child's daily life. Questions in the interview have each got a clearly stated purpose that gives the interviewer a clear sense of direction and focuses on the end result to be achieved at the end of each question. For instance, in the social verbalisation section, the questions the interviewer is expected to ask are about small talk, participating in language interchange at present and when the child was younger. However, the purpose of the section as stated is to establish, if speech is used by the individual just to be friendly or social rather than just express needs or gather information. This fits in with ICD-10; 1(d) which is lack of spontaneous sharing by the individual. Although the administration of the interview requires a substantial amount of time, most parents find it a positive experience because they are allowed to describe important aspects of the behaviour in their own words, which helps them to have a better understanding of the factors, particularly social behaviours, that are pertinent for the diagnosis and important part of autism (Lord et al. 1994). A major part of ICD-10 asks clinicians to evaluate the communication and language skills and abilities. This is reflected in ADI-R, the major part of the interview is assessing the individual's language and communication ability from the parent's point of view both skills and ability at present and when young, in 40 out of the total 93 questions. This gives a more detailed account for the person diagnosing than could be determined only by observation in a clinic (Lord et al. 1994). In principle the ADI-R can be administered by someone who has had training in administering the interview (essentially by administering the interview 3 times) and after the person has established reliability for scoring with other experienced individuals (Lord et al. 1994). Nonetheless, substantial knowledge and experience of actually working with individuals and children with autism is essential for executing the interview in a manner that will gather all the appropriate information required for the diagnosis and be both sympathetic and empathic towards the parent of a child with autism. Otherwise the person may miss vital information even after asking all the prompting questions, and come across as very impersonal fact finder.

Each item on the interview is coded on a scale of 0 to 3 for current behaviour with a few exceptions i.e. when the behaviour would have been relevant only during particular age periods. For instance, imaginative behaviour is only appropriate for age group 4 to 10 beyond that in typical developmental stage the imaginative play phases out. Some items are coded for the presence of that behaviour 'ever' because individuals with autism either with behaviour therapy or classical conditioning therapy may have learnt to not perform certain behaviour however, the fact that they ever did behave in that manner would be enough for scoring purposes. A code of 0 is given when the autism specified behaviour is definitely not present, 1 when the specific behaviour is probably present but defining criteria is not fully met, 2 when autism specific behaviour is definitely present and occasionally a code of 3 is given to signify extreme severity. An algorithm for diagnosis has been generated by clustering items from the interview that most closely depict the specific ICD-10:DCR-10 and DSM-IV criteria. For a confirmed diagnosis of autism using ADI-R the person needs to score at least 8 for the social interaction algorithm, 8 for communication algorithm, 3 for repetitive behaviour algorithm and exhibit atypical behaviour in at least one of the three areas by the age of 36 months in the interviewer's or the parent's judgements.

6.2.4 Childhood Autism Rating Scale (CARS)

CARS (Schopler, Reicheler and Rocher-Renner, 1988) is a 15-item behavioural rating scale developed to identify children with autism, and to distinguish them from children with learning difficulties without the autism syndrome. The 15 CARS items incorporate Kanner's primary autism features and DSM-IV criteria. It was originally designed as a research instrument and is reasonably effective in discriminating autism children from children with learning difficulty.

The questionnaire is a quick screening instrument and has been widely used for research purposes. It is particularly useful in screening young children, however, older children and HFA children who develop strategies to function within social world may be misdiagnosed.

6.3 Theories of autism

Evidence from behavioural and neurophysiological data has enabled scientists to formulate theories of autism in order to explain this pervasive developmental disorder. There are numerous theories formulated which address phenotype, genotype as well as atypical neural system in autism population. Four of the theories proposed are considered in this section.

6.3.1 Theory of mind (TOM)

An individual is said to possess a TOM if they are able to attribute mental states both to others and self in order to explain a set of behaviour and predict behaviour

(Premack and Woodruff, 1978). False belief tasks have been used to test TOM because successful performance in these tasks requires an individual to impute a false belief to a mistaken protagonist in order to correctly predict the protagonist's behaviour. To succeed in these tasks participants must appreciate that people's actions are not determined by the real state of the world, but by their mental representation of the world, which may or may not be accurate. The two most commonly used types of false belief task are location change (Wimmer and Perner, 1983) famously known as "Sally-Anne" task and unexpected contents task (Perner, Leekam and Wimmer, 1987) famously known as "Smarties tube" task. The TOM hypothesis of autism states that attenuated TOM underlies the social and communication impairments that characterises autism and researches initially testing the TOM hypothesis have shown that children with autism and to some extent adults with autism are impaired in TOM tests (Baron-Cohen, 1989; Frith 2003, Leslie 1987; Happé 1994). Although numerous studies claimed that as a population individuals with autism are impaired in TOM and it is this that accounts for the social disorder there were a proportion of participants with autism who successfully completed the tasks in the presence of severe social communication impairment (Happé 1995; Bowler 1992). In order to explain the data fully TOM hypothesis has been given other names such as mentalising (Hamilton, 2009) and other more challenging TOM tasks have been designed such as 'reading the mind in the eyes' (Baron-Cohen, wheelwright, Hill, Raste, Plumb, 2001), 'strange stories test' (Happé 1994), plaster test (Williams and Happé 2009).

The core issue with the TOM hypothesis has been that while a proportion of autism participants have been impaired in TOM some have successfully completed the task as well as controls. Moreover various tasks designed to test TOM have subsequently been claimed to be either correlated to language (Lind and Bowler, 2009; Lewis, Murdoch and Woodyatt, 2007), IQ (Frith, Happe and Siddons, 1994) or on logical reasoning skills to 'hack out' a solution (Bowler, 1992) in contrast to a more intuitive way of responding like typically developing children. Since this research focuses on facial expression production and not necessarily on false belief or mentalising the TOM approach is of limited relevance hence not been taken any further in this research.

6.3.2 Weak central coherence theory

Frith and Happé, (1994) formulated this theory on the basis of the evidence that individuals with autism have enhanced ability to focus on local detail. As a result they fail to notice the coherent whole. The idea that people with autism make relatively less use of context and pay preferential attention to parts rather than wholes, can go some way towards explaining the assets and deficits seen in autism. So for example, Shah and Frith, (1983) explored the well established block design task with an autism sample and reported superior performance in locating the embedded figures due to the advantage in segmenting the original design. Presenting pre-segmented designs to typical and learning difficult controls significantly improved their performance and removed the advantage of the autism sample. While individuals with autism have the embedded figure advantage they lack superior processing of meaningful and patterned information over random or meaningless stimuli. For example, typical children are able to recall meaningful sentences better than random word strings whereas with children with autism, there is no difference in performance. Frith and Happé, (1994) reviewed the available evidence and suggested this cognitive style as 'weak central coherence' i.e. less influenced by background features and more inclined to attend the components, parts or individual features. In case of face processing and FE understanding the WCC would posit that in case of autism it is a general perceptual deficit that affects both face stimuli and non-face stimuli.

6.3.3 Social motivation hypothesis

The notion that children with autism lack social motivation is partly based on the DSM-IV (APA, 1994) criteria for autism (Dawson et al., 2005), which includes "lack of spontaneous seeking to share enjoyment, interests or achievements with other people" and " lack of social or emotional reciprocity" (DSM-IV, APA, 1994). According to this hypothesis, an impairment in social motivation results in reduced attention to faces as well as to all other social stimuli such as the human voice, hand gestures, gaze following and so on. Dawson et al., (2002) hypothesised that social motivation impairments in autism are related to difficulty in forming representations of the reward value of social stimuli. This may be due to abnormalities in (a) the reward system per se or (b) neural network that might be important for the perception of the social reward. Option (a) involves the dopamine system particularly in the OFC which plays an important role in mediating the effects of rewards on social behaviour. Both behavioural research and neuroscientists have reported a correlation between the severity in joint attention impairments and neurocognitive tasks that taps the orbitofrontal circuit (Dawson et al., 2002).

By the second half of the first year in an infant's life the anticipated reward value of a stimulus begins to motivate and direct attention towards the social stimuli. In case of autism, reduced attention to faces and other socially relevant stimuli from a very young age (Osterling and Dawson, 1994), would deprive the social brain of the needed input for normal development and specialisation, resulting in a failure to become the 'face expert' or 'expert processor' of face stimuli. This is consistent with Nelson, (2001) theory of experience-expectant developmental system, which essentially states that experience in a critical period drives cortical specialisation for faces. This would further result in a failure of specialisation of regions that typically mediate face processing and would be reflected in decreased cortical specialisation and abnormal brain circuitry for face processing, including FE processing.

The social motivation hypothesis relates to the development of neural circuits underlying face processing (see figure 6.1). It has been emphasised that it is not the lack of exposure to face stimuli is the problem; rather the lack of interest due to impairment in reward mechanism is the key factor in this hypothesis.

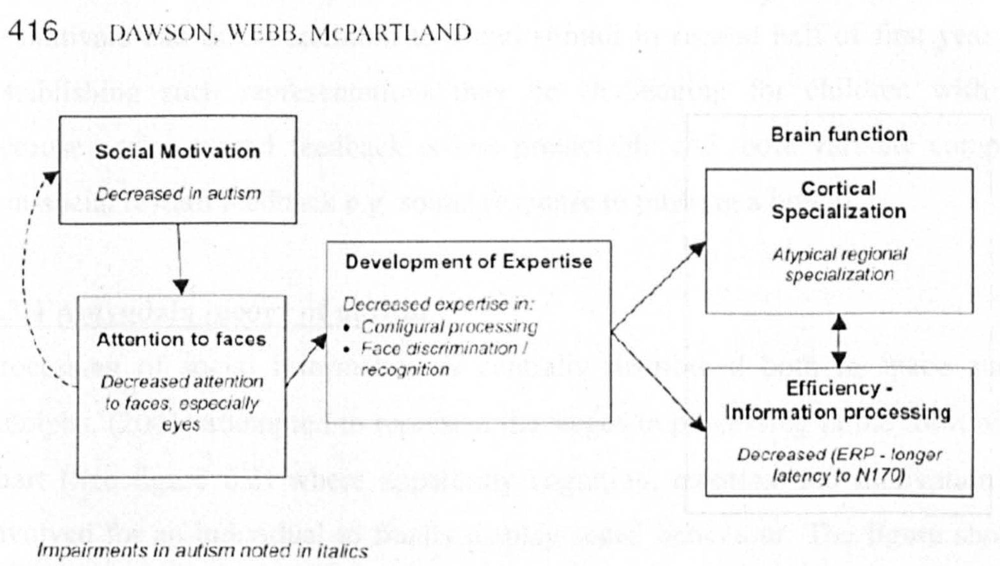


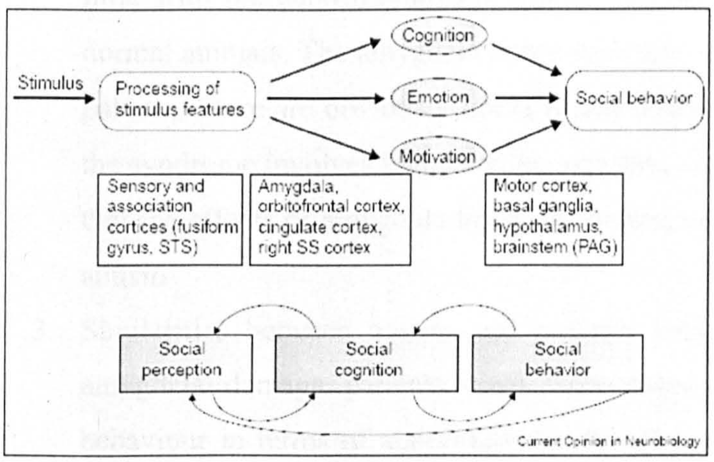
Figure 6.1: schematic diagram of the social motivation hypothesis drawing attention to the impact of early social disinterest on cortical specialisation. Reproduced from Dawson et al., (2005).

The social motivation hypothesis has been the result of numerous research with very young children with autism both behavioural as well as neuroscience (Dawson et al., 2000; Dawson et al., 2002). Studies based on home videos suggested that 8-10-month-old infants failed to orient naturally to social stimuli and one case study was reported where an infant was studied from birth to two years of age (Dawson et al., 2000). ERP of 3-5-year-olds with autism while viewing familiar and unfamiliar face and objects was recorded and compared with age matched control sample (Dawson et al., 2002). Typical children showed significantly larger P400 and Nc for unfamiliar face in comparison to a familiar face and to a favourite object in comparison to an unfamiliar object. Children with autism did not show a differential in brain response to familiar and unfamiliar faces, only objects. These findings led Dawson et al., (2002) to hypothesise that the neural mechanism that draws infant to social stimuli are dysfunctional in autism. It was argued that according to Nelson, (2001) and Johnson and Morton, (1991) the face processing cortical mechanism comes online from the second half of the first year. However, in case of autism, the lack of normal social attention leads to impairment in the neural system that comes online in the second half of the first year. The authors have suggested that this lack of intentional social attention is related to a fundamental difficulty in forming representation of reward value of social stimuli. Representations regarding the anticipated reward value begin to motivate and direct attention to social stimuli in second half of first year of life. Establishing such representations may be challenging for children with autism because social reward feedback is less predictable and more variable compared to non-social reward feedback e.g. sound response to pushing a button.

6.3.4 Amygdala theory of autism

Processing of social information is centrally distributed both in space and time. Adolphs, (2001) attempted to represent the stages in processing in the form of a flow chart (See figure 6.2) where apparently cognition, emotion and motivation all are involved for an individual to finally display social behaviour. The figure shows that sequence of events leading from perception of a social stimulus to elicitation of a social behaviour. The whole process is complex and involves multiple interacting neural structures. The neural circuits responsible for each of the tasks necessary to finally have a socially relevant output was also diagrammatically represented by

Adolphs, 2001 (See figure 6.3). This is similar to the neural basis of social intelligence suggested by Brothers, (1990), which involved the amygdala, orbito-frontal cortex and superior temporal gyrus. Taking all of this together 'social intelligence' was defined as our ability to interpret others' behaviour in terms of mental states (thoughts, intentions, desires and beliefs), to interact both in complex social groups and in close relationships, to empathise with others and predict how others will feel, think and act (Baron-Cohen et al., 2000). FE processing both recognition and production via modulation is a very small part of this complex system.



Component processes of social cognition. At the input end, social cognition draws upon neural mechanisms for perceiving, recognizing, and evaluating stimuli, which together provide the information required to construct complex central representations of the social environment. Regions in temporal lobe, such as the fusiform gyrus and the superior temporal sulcus, work together with a network of structures that includes amygdala, orbitofrontal cortex, anterior and posterior cingulate cortices, and right somatosensory-related cortices. Central processes of social cognition in turn modulate effector systems, which include motor and premotor cortices and basal ganglia, as well as systems more involved in emotional output, such as hypothalamus and periaqueductal gray (PAG). Importantly, social perception and social behavior are causally connected as aspects of social communication, as indicated at the bottom of the figure: an organism's production of social behavior in turn functions as an important source of perceptual input. SS, somatosensory; STS, superior temporal sulcus.

Figure 6.2: diagrammatic representation of social cognition process and the neural circuits involved for each of the tasks involved in social cognition. Reproduced from Adolphs, 2001.

Having defined social intelligence and recognised that individuals with autism are in deficit in social intelligence; Baron-Cohen collated neurophysiological data available in the literature regarding children with autism's abnormality in the areas specifically required for social intelligence. Of the three main areas necessary for social cognition and social intelligence to perform optimally is the amygdala, and all impairment of the amygdala in the case of autism both anatomically, neurologically and functionally was emphasised as follows:

1. Post-mortem evidence – neuroanatomical study of autism at post-mortem found microscopic pathology, in the form of increased cell density in the amygdala (Baron-Cohen, 2000).
2. Animal model of autism – the only animal model of autism involved ablation of amygdala. Bachevalier, (1991, 1994) lesioned either the medial temporal lobe or the hippocampal formation and amygdala separately in rhesus monkeys. The lesioned animals were raised and paired with age-matched control animal. These studies reported that medial temporal lobe lesion infants at 2-months of age were more passive, displayed increased temper tantrums and initiated fewer social contacts. At 6-months of age they interacted very little with the control animal and actively withdrew from all approaches by normal animals. The amygdala lesion monkeys showed very similar behaviour pattern. There are obviously limits to any animal model of autism, given that the syndrome involves higher-order cognition but Bachevalier makes the point that the effects of amygdala lesion in monkeys resemble certain symptoms in autism
3. Similarities between autism and patients with amygdala lesion - bilateral amygdala damage patients have been noted to display abnormal social behaviour in terms of abnormally trustworthy and a general positive bias in judging faces. Thus amygdala is not only responsible for judging threat from faces but also involved in complex judgements essential for regulating social behaviour (Adolphs et al., 1998). Adolphs et al., (2001) tested HFA, patients with bilateral amygdala damage and controls on facial expression recognition tasks as well as social judgement tasks. Although HFA were able to recognise facial expressions as well as controls but were similar to amygdala damage patients in the social judgment tasks such as trustworthiness of a face. This was consistent with the amygdala dysfunction hypothesis which suggests disproportionate impairment in the processes that subserve higher-level social cognition, with relative sparing of perceptual processing of faces, and of recognition of basic emotions (Adolphs et al., 2001). The data of this study was consistent with the idea that individuals with autism are able to form normal representations of faces and that they are able to retrieve knowledge regarding basic emotions expressed but that they fail to link perception of a face to the social judgements.

4. Structural neuroimaging – structural MRI have reported a reduced amygdala volume in individuals with autism (Baron-Cohen et al., 2000).
5. Functional neuroimaging - Baron-Cohen et al., (1999) tested six HFA on gender recognition and mental state labelling tasks while undergoing fMRI in order to investigate neural dysfunction in autism. The study reported that the areas previously stated responsible for social intelligence were confirmed to be so, amygdala, orbito-frontal cortex and STG were involved in facial expression processing and making social judgements from eyes. From the behavioural data it was clear that control sample was significantly better both in gender recognition and mental state labelling task. Left amygdala was found to be critically involved in identifying emotional information from complex visual stimuli e.g. eyes in case of controls. The autism group did not perform the tasks using the amygdala like the controls; instead a greater processing load was put on temporal lobe structures such as the STG for processing mental state from facial stimuli where only eyes were visible. The conclusion drawn by Baron-Cohen et al., (1999) was that autism population even the HFA perhaps solve the facial expression tasks using language and facial memory seats in the brain in compensation for amygdala abnormality.

Baron-Cohen et al., (2000) thus proposed that amygdala was an area that was abnormal in individuals with autism leading to atypical social behaviour and impaired social intelligence and presented the 'amygdala theory of autism'. The amygdala theory claims that individuals with autism have deficit in normal amygdala function; as well as the fact that amygdala fails to modulate other brain areas when viewing emotional stimuli. The theory also argued the idea that individuals with autism have alternative strategies for processing facial information essentially signifying a pattern of activity in autism brain that is both deficient and different.

6.4 Face processing

The diagnosis criteria as well as the theories of autism clearly indicate that individuals with autism are impaired in processing social stimuli. This specifically impacts face processing and FE processing. Individuals with autism have difficulty in social interaction denoting deficits in eye contact, gaze direction, joint attention, engaging in reciprocal interactions, reading others faces and inferring mental states and responding to emotional cues of others (Frith, 2003; Klin, Jones, Shultz, Volkmar and Cohen, 2002). Since autism is not diagnosed in most cases before 3 years of age (ICD-10, WHO, 1994; Filipek et al., 1999) it is very difficult for researchers to investigate the developmental path from infancy with respect to atypical face processing in autism. However, in a retrospective study, Osterling and Dawson, (1994) used videotapes of first birthday parties of individuals later diagnosed with autism, and reported basic impairments in social interaction such as lack of attention to others, failure of meaningful pointing, lack of gaze direction and no orientation to name. Dawson et al., (2004) investigated social attention impairments in 3-4-year-olds with autism. Social attention, which was coined to mean social orienting, joint attention and reaction to others' distress, was significantly impaired in 3-4-year-olds with autism in comparison to typically developing children (TD). Although a toddler's ability to use facial information such as gaze monitoring during joint attention is considered to be one of the critical discriminatory factor in early diagnosis of this disorder (Dawson et al., 2005) the current edition of DSM does not list abnormal face processing as a defining feature of disorder (Sasson, 2006).

Langdell (1978), in the seminal work on face processing reported the impairment in children with autism. In this study 9-14-year-olds matched to typically developing children of same chronological age and IQ were asked to recognise their peers from upright photographs. There was no group difference reported in this task. The next task was to recognise ones own peers from parts of faces presented, where by children with autism from both age groups were significantly better at recognising faces from the mouth region presented in isolation. In contrast, control sample found FR of peers easier from eye region alone. This study showed that while children with autism are able to recognise a familiar face without difficulty the strategy used is very different to TD and in general the information from the eye region is not used by individuals with autism.

In general it has been established that individuals with autism tend to focus on parts and have difficulty in deriving global information about the stimuli. For example, individuals with autism fail to take the entire visual context into account (Happé, 1996; Ropar and Mitchell, 1999); fail to perceive geometric figures which requires integration of parts (Mottron and Belleville, 1993); show enhanced ability to detect local targets in visual search task (Plaisted, O'Riordan, Baron-Cohen, 1998) and have been reported to have superior ability in detecting embedded figures (Happé, 1999). Theories have been formulated based on these findings such as weak central coherence theory (Frith and Happé, 1994) which will be discussed later on in the chapter.

As regards face memory in autism the general perception is that by middle childhood, children with autism are worse than a mental age and chronological age matched sample on a number of face processing tasks. This includes a face discrimination task (Tantam, Monogham, Nicholson and Stirling, 1989) and FR tasks (Boucher and Lewis, 1992). Tantam et al., (1989) compared children with autism and learning difficulty with controls matched on chronological age and nonverbal mental age on a test of finding odd face out from a set of photos of faces. The performance of the autism sample was not as good as the controls. Boucher and Lewis, (1992) assessed children with autism and learning difficulty and matched controls for FR. The authors reported that FR for unfamiliar face in autism sample was impaired in comparison to sample match on verbal ability and sample matched on nonverbal ability. A control task of building recognition was also administered to all the participants and there was no group difference in accuracy performance on the building matching task. This impairment continues into adulthood where adults with autism have been reported to be worse than age and IQ matched samples.

Hobson, Ouston and Lee, (1988) extended on this study, and presented adults with autism, in the test phase faces which were either full face or partially obscured. The task was face recognition based on identity or emotion. In the case of full FR, participants were as good as the controls, both in emotion and identity tasks. However, when partially obscured faces were to be recognised, participants with autism were better than the control sample when only the mouth was blanked. On the surface, this contradicts Langdell, (1978) findings to a limited extent, where it was reported that children with autism use information from mouth region more than TD. However, on closer inspection of the data presented it is apparent that, one, the participants in Hobson et al., (1988) study were adults and two, the performance of FR is only better for identity task. This advantage disappears for the emotion recognition task, where the individuals with autism were worse than controls when information from the mouth region was not available. The authors concluded that "if in the case of autism, we ask: what's in a face? We can reply that autistic individuals probably recognise something about another person's identity, but doubt if the autistic individuals fully grasp the feelings that a person's face may express" (Hobson et al., 1988). This study highlighted that although children with autism may be impaired in FR; adults with autism quite often develop strategies such that in an FR behavioural task there may not be a significant difference in performance. Similar results were also reported by Tantam, Monogham, Nicholson and Stirling, (1989). A parsimonious conclusion that can be drawn is that individuals with autism may differentially attend to different facial features in comparison to typical population (Sasson, 2006), thus leading to significantly different performance on finer aspects of face processing.

It is apparent that adults as well as children with autism are impaired in face processing especially when it is an unfamiliar face. Moreover, the strategy used to process faces by individuals with autism has been demonstrated to be atypical where the focus has been on the mouth region rather than the eyes as in TD. This may perhaps link somewhat to the lack of joint attention and impairment in gaze following and gaze direction in early childhood, if the focus is not on the eye region then one cannot be expected to have the ability to process information from this region.

As discussed in chapter 1, humans are considered as face experts because they process face stimuli faster and more efficiently than other physical objects such as houses, cars etc. One of the main reasons for such expertise is because faces are processed holistically; the individual features are glued together and seen as a whole gestalt rather than processing individual features (Galton, 1879; Tanaka and Farah, 1993). Configural processing on the other hand means perceiving the distance between the features accurately (Mondloch et al., 2002). Evidence is presented here on how individuals with autism, adults as well as children, fare on the FR tasks investigating both holistic and configural processing.

6.4.1 Whole-part face effect

With a backdrop of general impairment in face processing and atypical strategy being used by individuals with autism Joseph and Tanaka, (2003) used the whole-part paradigm to investigate if children with autism are impaired in holistic face processing. Twenty two children aged 8 to 14 and diagnosed with autism were matched to non-autism sample on full scale IQ and tested on the whole-part face paradigm with upright faces. The idea was if children with autism process faces holistically, they will show a whole-face test advantage i.e. when face parts are presented in context of the original face, accuracy will be higher. Children with autism did demonstrate holistic processing i.e. a whole-face advantage only when the mouth was presented in context. In fact, for the mouth area, stimuli accuracy was even higher than control sample. On the other hand, when recognition had to be based on eyes, performance was very poor, worse than that of the control group. This was consistent with Langdell, (1978), once again emphasising atypical faces processing in individuals with autism at the very least; and highlighting that holistic processing is not very effective.

6.4.2 Inner outer face effect

A more comprehensive paradigm to assess holistic face processing is investigating face identification ability using either inner part of the face or outer part of the face. The inner outer research in TD as well as children with autism will be reviewed in chapter 7.

6.4.3 Inversion effect

Typically developing children are slower at FR if the faces are presented as inverted faces (Yin, 1969). Children with autism on the other hand, are better at recognising inverted faces compared to control sample. Hobson et al., (1988) presented adults with autism, identity recognition tasks where in the test phase stimuli were inverted faces. Participants with autism were significantly better than the control sample in both identity and emotion recognition from inverted faces. Whatever the psychological processes underlying inverted face recognition, it was concluded that autism population employ processes or strategies that were different either in kind or in efficiency than the control sample (Hobson et al., 1988) enabling them to process inverted faces more accurately than controls. Lack of inversion effect in adults with autism was concluded to signify that they perhaps continue to use featural face processing as adults and the qualitative shift to configural processing does not occur, because inversion disrupts configural and not featural face processing (Sasson, 2006);

suggesting that the visual expertise for faces does not fully develop in individuals with autism. It should be pointed out here that Hobson et al., (1988) subsequently matched autism sample with controls on a one to one basis both for chronological age, verbal and non-verbal mental age and the significant difference disappeared. This signifies that adults with autism were susceptible to inversion albeit not to the same degree as the controls, when the matching was more even. The lack of susceptibility to inverted faces has been reported in other studies as well (Boucher and Lewis, 1992; Davies, Bishop, Manstead and Tantum, 1994). A prudent conclusion can be that perhaps autism population is not as effective in processing faces configurally as control sample.

6.4.4 Configural face processing

Rondan and Deruelle, (2007) presented adults with autism and control sample a schematic face in conjunction with two other patterns: its local and configural match, local choice differed in interspatial distance but had exactly the same elements as the main face and the configural match differed in local elements but had the same interspatial distance.

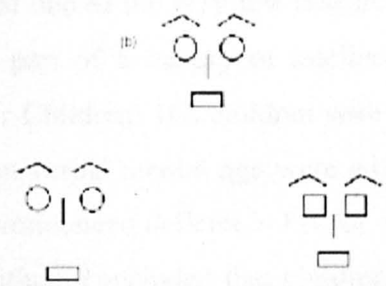


Figure 6.3: schematic face stimuli varying in either local features (face on the right) or configural information (face on the left) presented in 'same different' task. Reproduced from Rondan and Deruelle (2006).

The autism sample were significantly different to controls in that they had a local bias i.e. when asked to chose same face as shown previously they were focussing on local features and choosing faces that matched for local features (See Figure 6.3). This study confirmed that adults with autism continue to be deficient in configural processing unlike typical individuals, who develop visual expertise in face processing which essentially means sensitivity to configuration from adolescent years.

Behrmann et al., (2006) recorded accuracy as well as reaction time in a configural processing task for adults with autism and matched controls. The authors noted that although there was no significant group difference in accuracy performance there was a significant group difference for reaction time, autism population being slower at processing faces for gender as well as identity. More specifically there was interaction, underscoring the configural processing deficiency, autism sample were slower in identity task in comparison to the gender discrimination task. This illustrates clearly that an individual with autism may not be impaired completely in face processing as stated previously, but it is a case of more a subtle impairment, specific deficiency in configural processing leading to perhaps an inability to process the most salient social stimuli 'the face'.

Face processing impairment which has been observed in first years of life (Osterling and Dawson, 1994) although seems to recover to some extent enabling autism individuals to process faces at a simplistic level; this ability never reaches the visual expertise level for face processing as in typical adults.

Klin et al., (1999) reported one of the very few researches which used a standardised FR assessment which is part of a battery of intellectual assessment the Kaufman Assessment of Battery for Children. 102 children with autism who were matched on chronological age and non-verbal mental age were administered the aforementioned test. The study reported pronounced deficits in FR for children with autism compared to control sample. The authors concluded that children with autism have FR deficits that cannot be attributed to overall cognitive abilities or task demands. This was one of the seminal studies which tested such a big sample size with a standardised FR task and compared the data with matched sample. Having controlled task demands and group difference the face recognition still differed, enabling researchers within the field to come to the conclusion that individuals with autism have face processing deficit.

In general the eye tracking studies supported the above claim. Pelphrey et al., (2002) used eye tracking to investigate the visual scanpaths of high-functioning autism (HFA) adults while they were viewing faces. The participants spent significantly more time viewing external areas of the face and significantly less time viewing inner face.

This was consistent with previous research highlighting that individuals with autism pay less attention to faces and specifically eyes. This was conclusive evidence of the aberrant processing strategy used by individuals with autism when viewing faces. Klin et al., (2002) applied the eye tracking method to a social situation and examined the scanning behaviour in adolescents with autism. HFA were asked to watch a video clip of high emotion content while eye tracking was used to investigate visual scanpaths. The control group fixated on the eye region 2 times more than the autism group. The autism group in contrast fixated more on the mouth region and on the objects in the frame than on faces.

6.5 Facial expression

Kanner (1943) described one five year old as having "no affective tie to people" and the main point driven home was the profound lack of affective contact with other people with the striking feature of general inattentiveness to faces. Kanner concluded that autistic individuals appear to have "come into the world with innate inability to form the usual, biologically provided affective contact with people" (Kanner. 1943). One of the hallmark features of autism is a significant qualitative impairment in social interaction (DSM-IV, APA, 1994). There was an assumption in the original reporting of autism that facial expressions in specific and emotion in general are something innate in humans i.e. genetic predisposition. On the other hand, evolutionary psychologists have claimed that social cognition is something that has evolved in creatures that live in groups. Research in FE as stated in the previous chapter has taken both of these angles for investigation, continuing the debate of nature and nurture very strongly. Autism being a social disorder has benefited somewhat from this because research in FEs, emotion and social cognition both behaviourally and neurologically has tended to focus on autism population.

We first look at behavioural data highlighting the impairment in FE processing and finally the neural basis for this impairment, linking it with possible theories for autism and impairment in FE and emotion processing.

Autism is a neurodevelopmental disorder strongly characterised by deficits in social interaction that persists in people with autism who have IQ in the normal range

(Baron-Cohen, 1997). Impairment in FR in the case of autism has been well established in the previous section. Persons with autism particularly those with higher ability have been reported to better in labelling and identifying emotions (Oznoff, Pennington, Rogers, 1990), and performance for simple FEs such as happy and sad is better (Baron-Cohen, 1991) than complex emotions such as surprise. Spezio et al., (2007) tested high functioning adults with autism for FE recognition task using Ekman faces for all six expressions. HFA adults were no different in accuracy than the matched sample in judgement of basic FEs. This finding was different from those reported earlier and numerous reasons for this were given by the authors. Firstly, the sample used was HFA adults which may mean that by adulthood at least the HFA develop strategies albeit different to accurately recognise FE. Secondly, the matched sample was matched both for IQ and chronological age and this perhaps dissipated any difference.

Hobson, (1986) filmed himself whilst enacting happy, angry, unhappy and fear expressions. Children with autism and control sample matched for chronological age and non-verbal intelligence were asked to match the vocalisations and gestures to appropriate FE. Children with autism were reported to be significantly worse in this matching task highlighting the deficit in FE processing. Similarly, Loveland et al., (1995) also reported that autism sample were significantly worse than developmentally delayed matched sample in matching vocalisation with corresponding FE displayed on video.

Weeks and Hobson, (1987) tested 15-year-old children with autism and controls matched for verbal and non-verbal IQ with a FE sorting task. Participants were asked to sort faces by posting in one of the two boxes. Individuals with autism sorted faces on the basis of paraphernalia (hats) they were sporting and not on the basis of FEs. They failed to implicitly notice difference in FE while sorting and tended to focus on a feature such as the hat. Even when explicit instruction was given to sort according to FEs they failed to notice the difference in expressions. Consequently, it was concluded that the autism sample failed to process FEs both implicitly and explicitly and tended to focus on feature based processing and missing out on subtle information available in the face.

Celani et al., (1999) tested children with autism and a control sample for matching FE task as well as sorting by preference task. Participants were first presented with happy or sad faces and then presented with three faces (one of them same as the previous face) and the task was to pick the same face as seen before. The sorting by preference task meant that participant was presented with neutral and happy face and they have to choose the face they prefer. The autism sample was significantly worse in matching FE of happy and sad. In the sorting by preference task, matched sample participants preferred happy faces whereas the autism sample did not prefer happy over neutral faces. The conclusion drawn was that individuals with autism have a specific difficulty whereby they fail to recognise happy and sad faces and do not prefer a happy face over neutral face, like the typical population. It should be pointed out that in this study only individuals with severe autism were selected to take part in order to make sure that the autism sample definitely had the disorder. This may have resulted in autism sample failing to match basic expressions such as happy and sad because Gepner et al., (2001) demonstrated that children with autism as young as 5-6-year-olds can recognise happy, surprise, sad and disgust. On the other hand, Riby, Doherty-sneddon and Bruce, (2008) tested children with autism and matched controls with FE recognition and matching tasks. Children with autism were significantly less accurate than matched controls in happy, sad, angry and surprise FE recognition. In conclusion, the FE recognition research in children with autism has produced mixed results. In the same light Gepner, de Gelder, and de Schonen (1996) tested participants with autism with a battery of FR and FE discrimination task and reported that individuals with autism were impaired in various face processing tasks but not to the same extent. Participants were most impaired in FE processing compared to other aspects such as identity recognition, gaze detection and facial speech discrimination task.

Spezio et al., (2007) used a novel paradigm to investigate FE processing ability, i.e. the 'bubbles method'. In this method a face is revealed gradually and random areas are revealed in order to make emotion judgments of a face. Participants were shown happy and fear faces and the task was to decide the expression of the face. Faces were masked and different areas were revealed till finally a judgement was made. HFA adults were no different to the matched sample in accuracy or reaction time; however the difference was in the specific face area used to make such judgements. Controls relied more on information from the eyes to decide if the face was happy or fearful whereas HFA adults relied more on information from the mouth region. This confirmed a previous finding reported by Klin et al., (2002), which concluded that when viewing naturalistic social situations, individuals with autism demonstrate an abnormal pattern of fixation and pay less attention to eyes and more focussed attention to mouth, body and objects.

In a more recent research reported by Boraston, Corden, Miles, Skuse and Blakemore (2008) gaze behaviour was investigated using an eye tracking method. Participants viewed genuine or posed smiles and were asked to discriminate between the two. At the same time gaze behaviour was recorded using eye tracking equipment. Individuals with autism were impaired in the discrimination of posed from genuine smile and the pattern of eye gaze in the autism group was such that they were looking significantly less at the eye region compared to controls.

6.6 Evidence from neuroscience for face processing and FE processing

The system that sub serves face processing includes but is not limited to the following:

1. Lateral fusiform gyrus (FFA), important for structural encoding of faces and rapid FR (Kanwisher et al., 1997).
2. Superior temporal sulcus (STS), implicated in processing dynamic changes hence especially involved in processing mouth and eye region (Pelphrey and Carter, 2007).
3. Amygdala, important for analysis of FEs, perception of fear stimulus and general discrimination between various FEs (Baron-Cohen et al., 1999; Adolphs, 2001; Blair et al., 1999; Morris et al., 1998; Vuilleumier et al., 2001).
4. OFC, involved in processing the reward value of social stimulus (Dawson et al., 2005) as well as modulating feedback to subcortical structures (Adolphs, 2001) and along medial frontal cortex recalling the stored memory on facial expressions and emotion meaning.

5. Anterior cingulate gyrus and insula, involved in processing disgust (Phillips, Young, Senior, Brammer, Andrew, Calder, 1997).

6.6.1 Evidence of atypical neural system for face processing in adults with autism

N170 has been established as a temporal marker signifying early face processing with a distinct pattern of electrical brain activity. This component slopes negatively in adults, peaks at approximately 170 msec after stimulus onset over posterior temporal lobe. It is faster for faces and eyes alone and larger amplitude for inverted faces. In the first published report of N170 in adolescents and adults with autism McPartland et al., (2004) discovered an altered N170 pattern. HFA exhibited slower N170 to faces in comparison to furniture and failed to show a face inversion effect. In addition the speed of processing was slower correlating to the behavioural performance of FR. This study provided evidence of disruption in early structural encoding of faces characterised by slower speed of processing. In addition, there was evidence at least in some participants that the right hemisphere specialisation did not exist in case of autism sample. Therefore, it can be concluded that in autism the cortical circuit corresponding to N170 is functionally different to TD. The presence of atypical cortical representation led to the conclusion that it is not only a temporal difference in face processing with autism sample rather an aberrant neural circuit resulting in less efficient processing strategies.

FE recognition has been demonstrated to be very early: 80 to 110 msec after stimulus onset at midline occipital cortex followed by fusiform gyrus activation at 160 msec (Halgren et al., 2000). Several fMRI studies have shown that adolescents and adults with autism have reduced levels of activity in FFA to images of human faces (Critchley et al., 2000; Shultz et al., 2000). Shultz et al., (2000) tested 14 HFA and Asperger syndrome adults and matched sample with FR task while recording brain images. The study reported significant hypoactivation of the FFA area compared to the control sample, when the participants were doing FR task but the brain areas for object discrimination were activated to the same level as controls for object discrimination task. Critchley et al., (2000) demonstrated the effect in a group of 9 adult males with diagnosis of autism or Aspergers, using a active face perception task requiring the participants to categorise faces as expressive or not, replicating the hypoactivation.

Shultz et al., (2005) linked the hypoactivation of FFA with the Nelson, (2001) development of face recognition 'experience-expectant' theory and concluded that experience in a critical period is essential for the cortical structures to develop and acquire the expertise. As children with autism do not naturally orient to faces they fail to develop the cortical plasticity and hence lack of expertise. Consequently FFA hypoactivation is a result of autism and not a cause of autism.

The STS region has a differential activation to gaze direction, direct and indirect gaze has a differential pattern of activation as does congruent and incongruent gaze direction (Pelphrey and Carter, 2007). However, in case of the autism population, this differential activation does not happen. The STS region also has been reported to be over activated when perceiving facial expressions which are atypical as amygdala and OFC are predominantly responsible for emotion processing (Baron-Cohen et al., 1999). The STS activation pattern in the case of autism demonstrates aberrant strategies executed by the autism population when processing face stimuli. STS region is used instead of the social brain areas and perhaps as a result it fails to process the subtle dynamic changes in faces.

Baron-Cohen et al., (1999) reported a fMRI study with HFA adults investigating the neural circuits for social cognition, essentially using numerous FEs where only the eye region information was available to participants. The task was to label the mental state from eyes using the famous 'mind in the eye task' while a brain image was being acquired. The areas of STG, amygdala and the prefrontal cortex were recorded and used in analysis. The left amygdala was found to be critically involved in identifying emotional information from complex visual stimuli e.g. eyes in case of control sample. But the autism group did not perform the tasks using the amygdala like the controls; instead a greater processing load was put on temporal lobe structures such as the STG for processing mental state from facial stimuli where only eyes were visible. The prefrontal cortex was less active in the autism sample but this difference was not significant. The conclusion drawn by Baron-Cohen et al., (1999) was that in the autism population even the HFA perhaps solve the FE tasks using language and facial memory seats in the brain, in compensation for amygdala abnormality.

Ashwin et al., (2007) reported a fMRI study investigating neural activity in various social brain areas in adults with autism during perception of fear, anger, disgust, surprise and sad FEs. Control sample showed significantly more activation in the left amygdala and left OFC compared to the autism sample; modulated activity in other areas of social brain processing emotional stimuli was observed in the control sample, not present in the autism sample. These findings were in line with previous data available confirming dysfunctional activity in social brain areas in case of autism. These findings were also consistent with data from patients with amygdala damage. In individuals with autism amygdala also failed to modulate activity in other relevant social brain areas during perception of various emotional expressions.

Pelphrey et al., (2007) investigated the effect of dynamic FEs on the brain activity in HFA adults. Participants viewed dynamic fear, anger and neutral FEs while undergoing fMRI. The activation of amygdala was exactly the same as previously reported by Critchley et al., (2000); Baron-Cohen et al., (1999) and Ashwin et al., (2006); left amygdala hypoactivation and no modulation. The dynamic FEs did not change this result. The FFA and STS region showed a lack of modulation to FE and dynamic nature of stimuli. Overall, this study demonstrated very well that the social brain areas are dysfunctional in autism and the nature of the face stimuli, whether static or dynamic, did not change such conclusion.

6.6.2 Evidence of atypical neural system for face processing in children with autism

In typical developing individuals, N170 undergoes a prolonged period of development and a precursor to adult N170 has been identified in children (de Haan and Nelson, 1996) which does not have a negative deflection and has longer latency peaking at anywhere between 270 msec to 400 msec after stimulus onset. Webb et al., (2003) and Webb et al., (2005) investigated the equivalent of N170 component in children with autism aged 3 to 6 and compared them to matched controls. Unlike TD, children with autism showed larger amplitude to objects compared to faces and had shorter latency for objects compared to faces. Thus, it appeared that early on, in individuals with autism the speed advantage for face processing is not present for faces, as in TD.

Dawson et al., (2002) investigated ERP of familiar and unfamiliar faces versus familiar and unfamiliar objects in 3-6-year-olds with autism and age matched controls. TD showed differential ERPs to unfamiliar and familiar faces at P400 and frontal Nc component. Children with autism failed to show differential ERPs to familiar versus unfamiliar faces at either component but did show differential ERPs to familiar and unfamiliar toys at both the component i.e. P400 and Nc. This was taken as evidence that there is a specific impairment in face representation in autism and this data was later used to formulate a hypothesis for autism and social disorder, namely the *social motivation hypothesis.* This finding was confirmed by Webb et al., (2006) with a bigger sample size of 63 children with autism and similar size matched controls, where the finding was exactly the same; atypical scalp topography and faster latency for toys. Thus, children with autism as young as 6-year-olds have defiant processing strategy where by the FFA and STS region are not used for face processing tasks resulting in lack of expertise and speed.

Nelson and de Haan, (1996) reported a negative central component (Nc) in response to fear faces compared to happy faces establishing that typically developing infants as young as 7-month-olds have specialised cortical pathways responding differently to different FEs. So, typically developing infants have specialised neural pathways for processing FE which develops all through the adolescent years. However, in case of autism firstly the cortical specialisation does not follow the same pattern and secondly never reaches the expertise level.

Dawson et al., (2004) showed 3-4-year-olds with autism and matched controls a face with fear and neutral expression while recording ERP. N300 was recorded and reported which is the same as adult N170; a negative peak after 300 msec of stimuli onset in the posterior scalp area especially for right hemisphere. The 300 msec sharpens to 170 msec by the age of 5 in typical children. Children with autism had significantly slower brain response to fear (N300) compared to typical sample. They also failed to show differential ERP as shown by typical sample. Furthermore, the scalp topography for fear faces was aberrant in case of children with autism. The latency signified the speed of processing fear faces being compromised and abnormal topography signified lack of cortical specialisation and atypical recruitment of cortical areas.

While cognitive neuroscientists have generated a wealth of information regarding the brain regions involved in social cognition and perception, very little work has been done to evaluate the development in children perhaps due to the constraint of testing and hence clear developmental pathway as regards the deficits are still to be explored.

6.7 Theories of autism accounting the FR and FE impairment in autism

In order to explain the various features of the disorder, a number of theories have been proposed and supported with data to demonstrate the atypical nature of autism. Since this thesis is investigating FR and FE production it has led me to look closely at the theories that explain the face processing and FE processing deficits. To that end, I will consider a theory that has predominantly taken the behavioural data into account and formulated the *social motivation hypothesis* and a theory that has taken neuroscience data into account and formulated *the amygdala theory of autism*. General theories which encompass all deficiency in autism such as the *weak central coherence* (WCC) has also been used occasionally to explain the specific impairment more in FR.

6.7.1 Weak central coherence

One possible explanation for why persons with autism have difficulty in processing facial information is that they experience a fundamental deficit in perceiving features of objects and persons and forming coherent and meaningful wholes. As explained earlier this has been referred to as weak central coherence theory (Frith and Happé, 1994). For face and FE processing it would claim that there is less inclination to perceive faces as meaningful wholes. Persons with autism have been shown by behavioural research to attend to specific regions or features of the face for information i.e. focus on the mouth region, lack of gaze perception, avoid processing eyes etc. However, there are numerous studies that have demonstrated that individuals with autism perform at a level similar to typical individuals and those studies would counter the WCC argument.

6.7.2 Social motivation hypothesis

The lack of perceived reward from face stimuli might ultimately result in a lack of attention to social stimuli, including faces and facial expressions, thereby creating a deprivation of normal learning experiences with faces. The amygdala is essential in assessing and judging emotional valence of a stimuli and because children with autism have dysfunctional amygdala they fail to develop emotional meaning memory, which then is not accessible when reward feedback is needed, further impairing the reward mechanism. Thus the social motivation theory highlights impairment of the amygdala and orbito-frontal cortex and the impact one impairment has on another.

Dawson et al., (2002) formulated the social motivation hypothesis based on the observation from the infant studies (Dawson et al., 2000; Osterling and Dawson, 1994) which clearly emphasised the lack of interest in social stimuli in children with autism. It is interesting that instead of concluding that a lack of interest in social stimuli leads to impairment in learning of reward value the theory goes beyond behavioural data and claims that it is actually the dysfunctional reward value which causes the disinterest in the face and not the other way round. This assumes more a neurophysiological and genetic impairment and the disinterest in face and social world is the result of autism not the cause.

6.7.3 The amygdala theory of autism

Ashwin et al., (2007) tested if adults with autism have differential pattern of neural activity in various social brain areas compared to typical adults. Participants were presented with fear, anger, disgust, surprise and sadness facial expression while undergoing fMRI and the results confirmed that autism involves an atypical pattern of activation within social brain during the processing of facial expressions of emotion. These differences were less activation in left amygdala, left orbitofrontal cortex and a lack of modulated activity in all the areas implicated with social intelligence. For instance when typical adults viewed fear faces activation in left amygdala was significantly more than for other faces but not in autism sample. This was concluded to reflect either a deficit in the ability to label social stimuli as emotionally significant or in the ability to use and integrate emotional information. Autism sample also showed significantly more activity in STS and anterior cingulate cortex. It should be noted here that it is not exclusively amygdala that has a hypoactivation in individuals with autism. Other brain regions that have been highly implicated in social intelligence such as the orbito-frontal cortex, STS, anterior cingulate cortex all show atypical activation in the autism sample. The OFC follows the same pattern as amygdala i.e. hypoactivity (Baron-Cohen et al., 1999) but the STS and anterior cingulate cortex has a pattern of over activity (Baron-Cohen et al., 1999; Ashwin et al., 2007). However, these areas were not singled out as the primary cause of autism or a primary cause of deficit in face and FE processing.

Unlike the social motivation hypothesis which considers the abnormality of both amygdala and OFC; the amygdala theory considers abnormality of amygdala exclusively and fails to present a more inclusive theory.

6.8 Limitations in research for face processing in autism

Although comparisons are made between all the studies conducted in this area to come to the common conclusion that there is deficits in face processing mechanism in autism we need to bear in mind that the diagnosis of the sample of autism used has been varied; the sample of autism population is very heterogeneous. The matched sampling has been very varied. Some researchers matched according to mental age others according to verbal or nonverbal or chronological age. Sometimes the chronological age of the match is much lower than the autism population because the sample has been matched for IQ. This does not seem to be a fair comparison especially when the research topic is faces as experience is one of major factors impacting FR results. Recent studies have taken on board that experience does have an impact on social cognition and hence in recent studies autism sample has been matched for both chronological age and IQ. However, once again this IQ and CA match is based on group means.

FEs used as stimuli have also been very varied. Some are very schematic and lose real life relevance; some are close to real life but lose experimental validity. Paradigms used have also been very varied. The innovative FE production paradigm used in this research will be discussed elsewhere in the thesis but the participants included in this research and selection and exclusion criteria are considered next.

6.9 Participants

This section describes participants who took part in the inner outer study as well as the FE production study, the selection and the exclusion criteria for participants in the different groups, the parameters used for matching the control samples and any limitations of the selected sample.

The ethics committee of Sheffield University, Psychology department and NHS trust of South Yorkshire approved all the studies in this thesis. Parents and schools were provided with written information covering the aims of the studies and explained the participant's tasks. Parents were required to give written consent for the child to participate in the study.

Researches in the field of autism have recruited only male participants. But both the studies reported in this thesis have recruited both males and females, in no definite proportion because this study is not investigating gender difference and primarily because of the constraints of recruiting individuals with autism as participants, recruitment was not limited to males only.

6.10 Recruitment

6.10.1 HFA group

Participants were recruited from numerous sources, including the volunteers from secondary schools in Nottingham and Sheffield, the National Autistic Society website and support groups for parents.

Information leaflet specified that the study was funded by research council, University of Sheffield and Nottingham. It also described the aims of the study, actual tasks involved and the time commitment required from the participants. An active consent was sought for participating and permission for videoing each participant was also sought. Information regarding the complaints procedure if the participant or the family was unhappy was provided along with named contact. HFA participants were tested either at school or at their home individually.

6.10.2 Matched controls

The matched control was recruited through mainstream secondary schools. Information was sent to school to pass it to parents providing them with exactly the same information as HFA participants.

6.10.3 Inclusion and exclusion criteria

To be included in the HFA group, participants had to have a diagnosis of Childhood autism or high functioning autism (HFA) by a clinician using ICD-10 (WHO, 1994) criteria. In addition 7 out of the 15 children with autism who participated were administered ADI-R (Lord et al. 1994), a semi-structured interview with the mother. All the participants scored above the cut off point in social interaction algorithm, communication algorithm, repetitive behaviour algorithm and exhibited atypical behaviour in at least one of the three areas by the age of 36 months in the parents' judgements. This was both one of the characteristics of this thesis as well as a limitation. The ADI-R training was acquired during the course of this research hence administering the ADI-R to individuals was definitely very useful in building personal skills both in clinical and research diagnosis. Due to time constraints the ADI-R could not be administered to all the participants and I had to rely on the diagnosis of the clinicians to a certain extent. However, Charman, (2006) stated that an experienced clinician's diagnosis is the most reliable method of diagnosing autism; bearing this in mind it was decided on balance to rely on the clinician's diagnosis for rest of the participants.

CARS was administered as a screening for autism questionnaire. Teachers or parents filled up the questionnaire independently and in their own time. CARS classified all HFA participants as 'mildly or moderately autistic' and participants in the MC groups as 'non-autistic'. It should be noted that these participants were 9-15 years old in mainstream education who have developed strategies for social functioning and interaction as a rule based system. CARS fails to pick up the subtle differences in communication and interaction as ADI-R does.

Facial expression recognition is dependent on verbal ability (Gross and Ballif, 1991) and in the facial expression production experiment labelling each emotion and certain level of comprehension was required. Taking this into account a second inclusion criterion was set to include participants with full scale IQ of above 70 (i.e. two standard deviations below average). Setting such an IQ threshold is one of the limitations of the study as it does not represent the wide spectrum of autism population.

Children with autism often get support in social and emotional skills development at school. Taking part in such skill development activity or belonging to any support group was not set as an exclusion criterion.

Both autism sample and matched control sample had exclusion criteria of diagnosis of mental illness, neurological difficulty, ADHD, dyslexia, reading difficulty and needed to have an IQ of above 70. No actual medical records were seen but verbal information provided by teachers and parents were relied on as far as other diagnoses were concerned.

Also children with diagnosis of Asperger syndrome were excluded because the diagnostic criteria for both are different according to ICD-10 (World Health Organisation, 1994) and the abilities may also be different.

6.10.4 Matching groups

In order to limit the influence of confounding variables as much as possible, participants were matched on several factors deemed relevant and important for facial expression and face recognition study: full scale IQ, chronological age and similar educational background. Each participant was matched individually for IQ, and chronological age.

Full scale IQ encompassing verbal and performance IQ was used to match the control sample as both of these have been found to predict facial expression and emotion understanding (Gross and Ballif, 1991; Buitelaar et al. 1999). Once again due to time constraints both from the research perspective and from the perspective of participants, Wechsler Abbreviated Scale of Intelligence (WASI), comprising the vocabulary, similarities, block design and matrix reasoning tests was used to test IQ instead of the full Wechsler scale. The WASI produces verbal, performance and full scale IQ scores, with correlations of .88, .84 and .92 with the full Wechsler scales (Wechsler, 1999).

The groups were matched for chronological age as facial expression recognition continues to develop right through adulthood.

6.10.5 Limitations of participant selection

Beyond the limitations already mentioned, one of the limitations of the studies reported here is relying on the clinician's diagnosis. Although Charman, (2006) stated that an experience clinician's diagnosis is the most reliable method of diagnosing autism; there is a small chance of a wrong or inaccurate diagnosis. Clinicians do not necessarily follow the ICD-10:DCR-10, which is stringent diagnostic criteria primarily for research purpose. It is wise to administer ADI-R (Lord et al. 1994) or ADOS-G (Lord et al. 1989) for a more accurate diagnosis. It should be noted that it was beyond the scope of the thesis to administer IQ tests, interviews for diagnosis and recruit autism and non-autism participants by single researcher.

6.11 Conclusion

The ADI-R is a semi-structured, investigator based interview for parents of children and adults for whom autism is a possible diagnosis. The revised version is linked more closely to ICD-10 and DSM-IV (Lord et al. 1994); whereby the 93 questions of the interview are clustered into three main sections which are social interaction, language and communication and interests and behaviours. The social interaction section has questions that cover criteria A1 of DSM-IV and/or subsection B1of ICD10:DCR-10, language and communication covers criteria A2 of DSM-IV and/or subsection B2 of ICD-10: DCR-10, finally interests and behaviours covers criteria A3 of DSM-IV and/or subsection B3 of ICD-10:DCR-10. DSM-IV and ICD-10:DCR-10 give equal weight to social interaction, language and communication, and interests and behaviour but ADI-R gives a lot more weight to language and communication, both expressive and loss of the expressive language, with 40 out of the 93 questions in the interview covering only language and communication.

The most striking difference is that DSM-IV and ICD-10 presumes vast knowledge and experience of the clinicians and only gives guidelines for diagnosis but the ADI-R is a very detailed step-by-step tool. This means that anyone with sufficient training is able to administer ADI-R. This perhaps means that diagnosis according to DSM-IV and ICD-10 may vary whereas ADI-R as a tool has high reliability. The disadvantage of ADI-R is that it is very time consuming and often researches having sample size of 15 to 20 will inevitably mean administering ADI-R to the whole sample as near impossible for individual researcher.

Theories of autism presented in this chapter highlighted that Baron-Cohen et al., (2000) proposed that amygdala was an area that was abnormal in individuals with autism leading to atypical social behaviour and impaired social intelligence and presented the 'amygdala theory of autism'. Dawson et al., (2005) propose the social motivation hypothesis, proposing a failure in the 'reward mechanism' due to impairment in OFC; consistent with Nelson's, (2001) theory of 'experience-expectant' developmental system, which essentially states that experience in a critical period drives cortical specialisation for faces. However, Shultz et al., (2005) linked the hypoactivation of FFA with the Nelson, (2001) development of face recognition 'experience-expectant' theory and concluded that experience in a critical period is essential for the cortical structures to develop and acquire the expertise. As children with autism do not naturally orient to faces, they fail to develop the cortical plasticity and hence lack of expertise. Consequently FFA hypoactivation is result of autism and not a cause of autism

Individuals with autism may be able to recognise familiar faces and this ability may already be established in childhood but overall unfamiliar face processing is impaired and this impairment carries on into adulthood. Paradigms used to test the configural and holistic face processing have clearly demonstrated that face expertise is never achieved by individuals with autism leading to piecemeal face processing (Dawson et al., 2005) and atypical strategies developed over the years where by information from the mouth region is used much more than information from the eye region (Klin et al., 1999; Hobson et al., 1989). This may perhaps link somewhat to the lack of joint attention and impairment in gaze following and gaze direction, if the focus is not on the eye region then one cannot be expected to have any ability to process information from this region.

In summary, behavioural data for face processing is conflicting on the surface. Adults with autism in some studies have been reported to achieve the same level of accuracy as matched controls (Langdell, 1978; Hobson et al. 1988). However, when processing strategy is explored, individuals with autism display atypical strategy for face processing focussing only on mouth region (Joseph and Tanaka, 2003) or on local features (Rondan and Deruelle, 2007). There also appears to be a speed accuracy "trade off" (Behrmann et al., 2006), when accuracy is achieved at the same level as controls the speed has been compromised. Thus, even though on the surface the results of face processing in adults with autism is conflicting; when looked deeper it is clear that adults perhaps are not using the configural and holistic face processing strategy as effectively as typical adults and that is where the impairment lies.

In children with autism FR, is not so impaired in older children (Langdell, 1978) compared to younger children (Klin et al., 1999) but the strategy used is atypical focussing more on information on the mouth region (Langdell, 1978; Klin et al., 2002) and being distracted by paraphernalia (Hobson et al., 1988).

Children with autism, especially those who are very high on the spectrum and severely autistic fail to recognise happy and sad faces and do not prefer a happy face over a neutral face unlike the typical population. Adults with autism fail to process facial expressions both implicitly and explicitly and tend to focus on feature based processing, missing out on subtle information available in face stimuli. This result is slightly mixed as some studies have reported that individuals are able to process facial expressions but the strategy executed is significantly different. In brief, it has been well established that a significant impairment in processing FEs exists in children with autism and this persists in adulthood. In adults especially in the case of HFA even when the accuracy level for recognition is the same as controls the strategy used is atypical.

Neurophysiological studies have detected impairment in both early (N170) and late (Nc) stage of face processing using ERP, deficit in FFA, STS, amygdala and OFC. A failure to show a speed advantage for processing faces as existing in typical population as well as atypical cortical topography, no right hemisphere specialisation in autism population for face processing means the final result being that individuals with autism are significantly worse at FR, FE recognition and general social interaction.

Neuroscience data proved that face processing impairments in autism is present early in life, at least by the age of 3 years. Studies have detected impairment in both early (N170) and late (Nc) stage of face processing using ERP, deficit in FFA, STS, amygdala and OFC. A failure to show a speed advantage for processing faces and the atypical cortical with no right hemisphere specialisation in autism population for faces means significantly worse at FR, FE recognition and general social interaction.

Chapter 7

Face processing using the inner outer face paradigm

Abstract

This chapter covers the literature for inner outer FR in typically developing children and the rationale for inner outer face recognition research of this thesis. The introduction section reiterates meaning of terms such as holistic and configural face processing particularly from the perspective of this thesis. The literature highlights that familiar and unfamiliar faces are processed differently by adults and children. In addition information from inner and outer face is used differently by adults and children. Since this thesis uses the inner outer face paradigm to investigate face recognition and is investigating unfamiliar face recognition evidence in literature from infancy to adults is presented in brief.

7.1 Introduction

It has been established that typical adults are 'face experts' as they are able to recognise thousands of faces, at least for a short time, including the ones they encounter briefly in the course of research. Behavioural studies have verified and confirmed that this expertise is due to holistic processing, which means face stimuli are processed by adults as a whole, glueing the features such as mouth, eyes, nose, ears all together into a gestalt, rather than piecemeal processing of individual components (Maurer et al., 2002; Taylor et al., 2004; Diamond and Carey, 1977). Another characteristic of face processing well established is that for processing mood, emotion, intentions and mental state; configural processing is essential, processing of the spacing between the individual features also called second-order relational processing (Maurer et al., 2002). However, these skills are only efficient when the face is in the canonical upright orientation. Neuroscience research has successfully associated the adult expertise with particular neural correlates: the N170 in ERP studies (Bentin et al., 1996) and increased activity in the FFA (Kanwisher et al., 1997) and STS region (Pelphrey and Carter, 2007) in fMRI studies.

This expertise in face processing does not emerge until adolescence (De Sonneville et al., 2002) with recognition ability improving remarkably from 7-11-years of age (Carey et al., 1980). Nonetheless, infants have mechanisms enabling them to naturally orient towards schematic faces at 9 minutes from birth (Goren et al., 1975), discriminate mother's face from a strangers face at 4 days of age (Pascalis et al., 1995); and it has been demonstrated that such a task executes specialised brain areas such as N290 and P400 (de Haan et al., 2002) in infants as young as seven months old. The quest has been to ascertain if this is due to a quantitative difference whereby gradual maturity leads to performance at adult level or if this is a qualitative difference whereby children process faces differently to adults. The qualitative difference is researched using paradigms such as inverted face processing (Yin, 1969; Valentine, 1988), whole-part processing (Tanaka and Farah, 1993), composite face processing (Carey and Diamond, 1994; Hole, 1994), spatial relation manipulation (Mondloch et al., 2002) as well as inner outer face processing (Newcombe and Lie, 1995; Ellis et al., 1979) . No experiment is needed to show that inner face parts are more important than outer face parts for functioning in the social world (Campbell et al., 1995). The evidence leans towards a qualitative difference because although maturity is a factor, it has been ascertained that children are immature at processing spatial relationship among features (Mondloch et al., 2002) and they tend to focus on the outer paraphernalia more than the inner facial features (Diamond and Carey, 1977) all signifying qualitative difference and perceptual style of face processing.

One of the claims on face processing strategy has been that TD tend to focus on outer parts of the face for identity decisions until the age of 10 (Diamond and Carey, 1977) and then gradually switch to focussing on the inner face. Research in the field of face processing in children with autism has attempted to investigate if the same developmental pattern exists in children with autism. As discussed in chapter 5 the FR research in children with autism has established that face processing is atypical and even when accuracy is at same level as TD the strategy for face processing is different (Joseph and Tanaka, 2003; Rondan and Deruelle, 2007); and this persists in adulthood (Behrmann et al., 2006).

Although research in the field of FR in children with autism has focussed on investigating if there is a deficit in face processing, there has been not much research using inner outer face recognition paradigm in order to investigate holistic face processing per se. Hence, before embarking on the second part of this research, which essentially is the main focus of this thesis, the holistic face processing in TD 6-10-year-olds and high functioning children with autism was investigated using inner outer face recognition paradigm.

7.2 Inner outer face recognition in typical population

7.2.1 Adults

7.2.1.1 Familiar face

Adults' face processing strategy has been established to be oriented more towards processing the inner face and less dependent on outer face parts such as the hairline, chin etc. especially for familiar faces. The outer face parts are more prone to frequent changes whereas the inner features are relatively stable over longer time period. Familiar faces are claimed to be processed using the inner face parts (Ellis et al., 1979) for recognition. Ellis et al., (1979) presented adults with only inner or outer parts of a familiar face for recognition, performance was better when only the inner face was available, as opposed to only the outer face. In the same study for an unfamiliar FR task both inner and outer features were used by participants equally in order to recognise the face.

7.2.1.2 Unfamiliar face

Young et al., (1985) used a face matching task and found that internal features of unfamiliar faces were matched equally as fast as the external features. Thus, in the case of adults familiar and unfamiliar faces are processed differently whereby for familiar FR, the inner face is processed but for unfamiliar FR both the inner and outer face parts are equally informative for adults, and FR is based more on the inner parts than outer. This was confirmed by O'Donnell and Bruce, (2001), who reported that for unfamiliar faces adults are more likely to detect changes made to hair styles than changes made to an inner face feature (e.g. eyes), meaning the outer face may have an advantage for unfamiliar FR in adults.

Bonner et al., (2003) took this one step further by testing adults for unfamiliar FR and examined if the recognition improved over a period of 3 days of familiarisation. Participants were presented with a face matching task where either the inner or outer face video was to be matched to full face stimuli. All throughout accuracy for matching using the outer face was better than matching using the inner face. The inner face matching improved over the 3-day period but the outer face matching remained stable over that period. The conclusion drawn from this study was firstly, familiar and unfamiliar faces are processed differently by adults; secondly, adults rely initially more on outer face parts for recognition and slowly switch to inner face processing as the face gets more and more familiar. On the whole, for unfamiliar face processing either both inner and outer face information is used equally or there is an outer face advantage.

One line of investigation has been, do children and infants behave the same as adults? It is claimed that children unlike adults focus on outer face for familiar and unfamiliar face recognition. The second line of investigation has been to ascertain the age when individuals switch to using inner face more and use the inner face information for recognition and establishing progressive lowering of the age. I am now going to review the literature for infants and children on inner and outer face processing and the use of information for FR.

7.2.2 Infants

As face experts adults process unfamiliar face differently to familiar face and use the information from the inner face selectively. Infants have been shown to have innate ability to orient towards schematic faces (Goren et al., 1975), highlighting that they can perform first order processing from about 9 minutes of being born. The question then is, do infants perform holistic face processing or differentiate between familiar and unfamiliar face using inner and outer face information?

7.2.2.1 Familiar face

Pascalis et al., (1995) presented 4-day-old neonates with the mother's face and a novel face and recorded looking time which showed that when the full face was visible, neonates looked longer at the mother's face. However, when a scarf was worn to occlude outer face, neonates were not able to discriminate the mother's face from the novel face. Therefore, it was concluded that neonates acquire representation of their mother's face where the outer face parts are an integral part, and discrimination is based more on the outer face information. It was inferred that infants can discriminate between familiar and unfamiliar faces when outer face information is available.

Bartrip, Morton and de Schonen, (2001) tested infants aged 19- 155-day-olds for inner outer feature preference of mothers face. Infants were shown either full face or inner or outer face of mother's along with a strangers and infants preferred mother's face till the age of 2-months and then the preference shifted to strangers face in full face condition. However, for inner or outer face condition the visual behaviour pattern of infants appeared unstable for mother's face, with outer face preferred at 25 days of age, inner face preferred at 40 days of age and again outer face preferred at 155 days. A prudent conclusion from this data can be that firstly, it is disturbing for infants to see a live face masked so that only hairline and chin is visible. Infants visual acuity is limited so the HSF information from face is not available even then at least the first order configurations are available. Not being able to see the contours of inner face may be disturbing and the authors highlight this fact by stating that on numerous occasions infants were distressed. It is this distress that may have shifted the preference to inner face in some age groups. Secondly, it appears that infants are capable of forming a holistic representation of the mother's face by the age of 40 days and if one source of information is removed it affects the looking behaviour.

7.2.2.2 Unfamiliar face

Turati, Cassia, Simion and Leo, (2006) presented infants 1-3-day-olds with either full, inner or outer face for habituation and then tested for visual preference paired with a novel face for full, inner or outer face recognition (See figure 7.1.) Infants were able to recognise an unfamiliar face to which they were experimentally familiarised. Moreover, they were able to recognise faces from inner or outer faces alone, although recognition from the inner face must have been harder because the sample size required to reach significance was much bigger than for outer face condition. This finding was contradictory to Pascalis et al., (1995) or Bartrip et al., (2001), but on closer inspection of the data the authors concluded that if the infant is habituated to the inner face they have no problem in recognising the inner face in the test condition. It is only the difference in stimuli in habituation and test condition that causes the perceptual conflict thus affecting the recognition pattern.

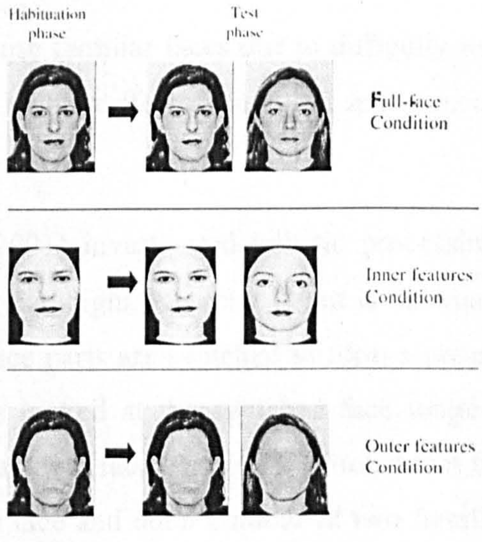


Figure 7.1: Stimuli used by Turati et al., (2006) to test infants aged 1 to 3 days old. Reproduced from Turati et al., (2006).

In order to prove this hypothesis, Turati et al., (2006) tested infants again with stimuli similar to what has been used so far i.e. habituation with full face and recognition with inner face or habituation with the inner face and recognition with full face (see figure 7.2).

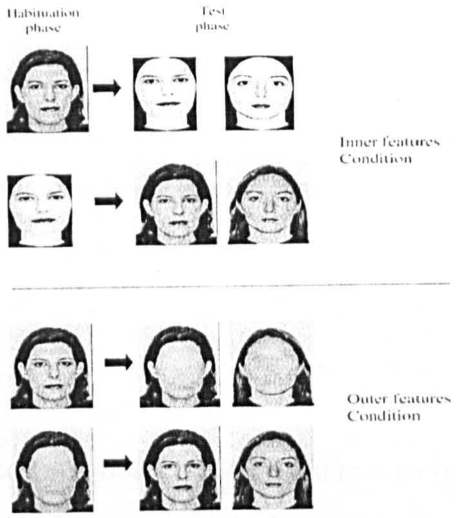


Figure 7.2: stimuli used in Turati et al., (2006) experiment 2 to test infants aged 1 to 3 days old. Reproduced from Turati et al., (2006).

Infants failed to recognise familiar faces due to difficulty in recognising a perceptual similarity between two highly different stimuli in appearance (Turati et al., 2006).

Cohen and Cashon, (2001) investigated holistic processing ability in 7-month-old infants with a 'switch' paradigm, whereby infant is habituated to two faces then the internal and external face parts are switched to form a novel face. Infants habituated to the 2 original faces looked at the switched face longer, demonstrating that the switch appeared to be a novel face. It should be noted that this is evidence of holistic processing as the inner face and outer contour of two familiar but different faces are glued together and perceived as a new face by 7-month-old infants. Holistic processing occurs not only among internal features but among inner face and external contour, making it difficult to recognise the inner face within a different contour (Young et al., 1987; Maurer et al., 2002b). Holistic processing is not only glueing internal features together, it can also be glueing inner face to the outer contour resulting in the face being perceived as a novel face.

Infants at birth are able to visualise the contour of the face and discriminate familiar and unfamiliar face predominantly from the outer face information and from 7 month of age perceive a face constructed out of the inner part of one and outer part of another habituated face as a novel face. So, some rudimentary discrimination between familiar and unfamiliar and holistic processing exists in infancy. To add to this if there is a perceptual difference between face presented for habituation to face presented for recognition it affects accuracy results.

7.2.3 Childhood

7.2.3.1. Familiar face

It has generally been accepted that children continue to use the outer face more for FR tasks especially at a younger age and they gradually switch to inner face processing as they get older. Both for familiar and unfamiliar FR, young children tend to focus more on the outer face. This is different from adults, who process the inner face more for familiar faces and the outer face more for unfamiliar faces. Campbell, Walker and Baron-Cohen (1995) presented 3-11-year-olds with whole, inner or outer familiar faces for a recognition task and found that up to the age of 7, children were better at recognising familiar faces from the outer face whereas children aged 10 and above were better at recognising familiar faces from internal features. Children recognised familiar faces better from outer face parts and at around age of 10 there was a switch to greater accuracy for internal faces. Campbell et al. (1995) state that "the present study can be construed as providing closely converging evidence for Carey and Diamond's "two-process" theory of configural processes in face recognition and suggests a possible reason for their findings." They go on to make it clear that "findings reported here should not be taken to indicate that children under the age of 10 are unable to make effective use of the configural information delivered by the inner parts of the face."

As stated earlier this switch from outer to inner face processing for recognition has been claimed to be due to development of configural processing and or holistic processing. In this thesis as only holistic processing is investigated I am only establishing links and interpreting results of previous research for holistic processing. Campbell et al. (1995) has been reported to reinforce the idea that firstly for familiar FR inner face is used more and secondly the age at which the FR is mastered has shifted continuously depending on the paradigm used. Holistic processing occurs not only among internal features but among the inner face and external contour, making recognition difficult when a familiar inner face is placed in a novel contour. Young et al., (1987) made composite faces from inner and outer facial features of well-known people and presented these for a FR task. These configurations were perceived as novel faces convincing that recognising parts of a familiar face was very difficult for the participants. Sinha and Poggio, (1996) presented identical inner face of famous people with different external contour and participants failed to recognise the similarity (see figure 7.3).

(b)

Figure 7.3: Gore/Clinton composite with identical inner face and different outer faces. Reproduced from Sinha and Poggio (1996).

Campbell et al., (1999) presented 5-15-year-olds with either full face or faces with blurred inner or outer face parts of famous people for FR. All age groups were not good in FR where the outer face was blurred and the switch to inner face was achieved at a much later age. Consequently, it can be inferred that glueing of the inner face to an external contour is a very strong phenomenon, making it difficult to recognise that inner face are the same.

7.2.3.2 Unfamiliar face

The advantage of familiar FR is that they have been viewed from various angles perhaps with different hair styles over a relatively long period of time and a stable memory formed. Unfamiliar FR data on the other hand, has been less clear. Ellis et al., (1979) tested 54 adults for unfamiliar FR by presenting them with one face at a time for 6s with a 3s interstimulus interval in the test phase. In the recognition phase either whole, inner or outer target as well as distracter faces was presented for same length of time and participants were asked to respond if they had seen the face before. The study reported that accuracy of judgement for inner or outer face was same, and concluded that face seen once may be assessed equally well by either the inner or the outer face parts.

Diamond and Carey, (1977) presented an unfamiliar face matching task to children 6-16 years of age. The task was to identify either inner face similarity or outer face similarity. This study reported that young children represent unfamiliar faces from isolated outer features such as hats, scarves etc. rather than the inner face. The switch to inner face was reported at the age of 10-12 years. It was concluded that by the age of 10 to 12 years children form a representation of an unfamiliar face that is based more on the inner face information, until then the children represent unfamiliar face more on the basis of paraphernalia. It may seem that the developmental pathway for identity recognition is that younger children rely on outer face information until the age of 10 years and then gradually switch to processing inner face information. As stated previously this was the famous, 'encoding switch' hypothesis.

Want et al., (2003) investigated unfamiliar face processing in children 5-9 years of age using the inner outer FR paradigm. Children and adults were presented with 3s video clips of unfamiliar male and female faces in the learning phase. In the test phase still photographs of a target face and a distracter which were either full or just inner or just outer faces were presented and the task was to match it to the previously seen video. 5-7-year-olds were better at recognising the unfamiliar face from outer parts than inner parts. Nine year olds and adults accuracy for the inner and outer face was not significantly different. Therefore, according to this study nine year olds behave the same as adults whereby the inner face disadvantage reduces significantly. This study also recorded reaction times which emphasised that children and adults make significantly faster and more accurate FR judgements from outer face information in comparison to the inner face. Based on the evidence reported by Want et al., (2003) it can be inferred that children as young as nine and seven years of age, process unfamiliar faces holistically in a manner that is similar to adults, where information from the inner and outer face is used equally but the judgements based on outer face parts are more efficient. One interpretation can be that until about the age of 10, children and adults process faces differently; not only are children less proficient in processing the inner face; they treat both familiar and unfamiliar faces the same whereas adults process familiar and unfamiliar faces differently. Children in general recognise faces from outer feature better and only later in life prefer the inner face. Conversely, adults recognise familiar faces from the inner face and unfamiliar face equally from inner or outer face parts. This notion has been challenged by Bonner and Burton (2004) who presented 7 to 11 year olds with a familiar and unfamiliar face matching task. Children as young as 7 years old processed faces in the same way as adults and demonstrated an inner face advantage in the matching task. This progressive lowering of age for switching from outer-face to inner-face has continued albeit using different paradigm and researchers have claimed that children as young as 4 can do holistic face processing at levels similar to adults (De Heering et al., 2007).

Mondloch et al., (2002) used one face stimulus called 'Jane' and manipulated it by modifying the features, external contour or spacing between the features to create 'sisters of Jane'. The external contour set had same inner-face placed in external contours of different shapes. For the external contour set accuracy of 6-year-olds was as good as adults tested in this experiment and the authors concluded that holistic face processing involving glueing inner face with external contour matures at the age of 6 for an unfamiliar face.

7.3 Inner outer face recognition in children with autism

Chapter 6 gave a detailed account of the deficit in face processing that exists in children with autism disabling them to function in the social world in a way that can be deemed effective. A number of investigators (Langdell, 1978; Hobson et al., 1988; Sasson, 2006) have appealed to the notion that individuals with autism are impaired in holistic face processing and fail to process inner face as efficiently as TD.

7.3.1 Familiar face

The inner outer face paradigm has not been used often to test face processing ability or processing strategy in children with autism. Wilson et al., (2007) used inner outer face paradigm to test familiar FR in children with autism aged 8 years and matched controls. Both groups had the inner face superiority effect in the FR task, similar to evidence available in the literature for typically developing children processing a familiar face.

7.3.2 Unfamiliar face

Weeks and Hobson, (1987) demonstrated that individuals with autism tend to get distracted with paraphernalia and sort faces on the basis of hats rather than inner face similarity. A parsimonious conclusion that can be drawn is that individuals with autism may differentially attend to different facial features in comparison to typical population (Sasson, 2006) thus leading to a significantly different performance on finer aspects of face processing.

Joseph and Tanaka, (2003) demonstrated that children with autism are better at processing individual face parts in isolation rather than in context of the face. The idea was that if children with autism process the face holistically, they will show a whole-face test advantage i.e. when face parts are presented in context of the original face, accuracy will be higher. Children with autism did demonstrate holistic processing i.e. a whole-face advantage but only when mouth was presented in context. In fact when mouth area stimuli were used accuracy was even higher than control sample. On the other hand, when recognition had to be based on eyes area stimuli, performance was very poor, worse than control. This study showed that children with autism can to a limited extent do holistic processing.

Rondan, Gepner and Deruelle, (2003) tested FR in children with autism using inner outer face matching paradigm for unfamiliar faces. Fourteen children with autism with mean age of 10 were individually matched to children with the same verbal mental age and chronological age and asked to match faces on the basis of either the outer or inner face. Children with autism performed equally well in both conditions but matched control had higher accuracy for the outer face, performance of typical children being in line with rest of the literature.

Wilson et al., (in press) tested children with autism for unfamiliar FR using full, inner or outer face during the test phase. It was reported that the autism sample performed at the same level as developmentally delayed and TD matched for verbal mental age but were younger in chronological age. It is difficult to conclude from such finding because TD sample in this study were younger to the autism sample which can be an indication of delayed development in the autism sample for FR. On the other hand autism sample has been described as low functioning so IQ can be a factor for FR effect.

In general, Children with autism demonstrate atypical face processing and inefficient ways of using inner and outer face parts for FR.

7.4 Conclusion

Adults process familiar and unfamiliar faces differently (Ellis et al., 1979) relying more on inner face features when processing familiar faces and equally distributing attention to inner and outer face features when processing unfamiliar faces.

The 'encoding switch' hypothesis claimed that children focus on outer-face parts more until the age of 10 years and then gradually switch to more inner-face processing. This claim has been challenged and the age at which children process inner-face has progressively been lowered (Want et al., 2003; Bonner and Burton, 2004; De Heering et al., 2007).

Holistic face processing in its entirety is glueing inner-face features together as well as glueing inner-face to outer-face contour (Young et al., 1987; Sinha and Poggio, 1996; Mondloch et al., 2002).

Children with autism show an atypical face processing mechanism and not very effective mechanism for holistic processing. Nonetheless, they do process faces holistically especially when information from mouth region is available (Joseph and Tanaka, 2003) and can recognise the face from inner-face only information (Rondan et al., 2003).

Although research in the field of FR in children with autism has focussed on investigating if there is deficit in face processing there has been not much research using inner-outer FR paradigm or research investigating holistic face processing per se (Joseph and Tanaka, 2003). Hence, before embarking on second part of this research which essentially is the main focus of this thesis, the holistic face processing in typically developing children aged 5-10 years was investigated. Holistic face processing ability in high functioning children with autism was investigated and difference between them and individually matched sample was investigated using inner outer face recognition paradigm.

Chapter 8

Thesis aims

Abstract

In this chapter I will explain the objectives of this thesis while looking back at the point when this research was conceived. Primary aims stated in chapter 1 are explained in detail and how I am going to achieve these aims are explained.

8.1 Producing facial expressions with and without context

The first and main aim was to investigate if children with autism can produce facial expressions and compare group differences with IQ and age matched on a one to one basis sample. However, this was completely uncharted territory at the time I started this research, and even since then, to my knowledge, there has been one study (McIntosh et al., 2004) which essentially reported implicit and explicit imitation by children with autism. Boraston et al. 2008 The literature is littered with concrete behavioural and neurological evidence that children with autism are impaired in recognising complex facial expressions such as disgust, but are able to recognise simple expressions such as happy and sad as stated in chapter 3. As I state in chapter 3, facial expressions and emotions not only involve recognising the expressions and being able to label them, but to regulate oneself and produce an appropriate response. One of the main criteria in autism diagnosis is abnormal or impaired development of reciprocal social interaction. Autism research has primarily evaluated this by questioning the ability to recognise emotions and facial expressions in the interaction. However, that is a small part of the whole social interaction conundrum, so I decided to investigate another aspect of this i.e. actual behavioural response in terms of facial expression production. Anecdotal evidence from parents provides us the information that it is not that children with autism do not feel any emotions, it is more that the way of expressing is perhaps atypical and sometimes there is lack of understanding the subtle and or complex emotions. It was then my aim to approach the facial expressions and emotion from a novel perspective and pose some fresh questions: Can children with autism control the facial muscle movements that are essential to produce facial expressions? Do children with autism have understanding of the facial expression labels and are able to correctly produce the expressions on demand without any context? Would the context help in production of facial expressions, in other words would context help inducing emotion and aid facial expression production?

8.2 Children with autism and holistic face processing

As mentioned above when this thesis was first conceived, the main aim was to investigate if children with autism can produce FEs and compare group differences with a matched sample. Before attempting to embark on such ambitious exploration, it was deemed logical to first establish if children with autism process the inner face for tasks such as identity recognition. The rationale behind this decision was two fold firstly; it will be highly improbable to investigate FEs with my sample of autism participants if they do not attend to the inner face. Secondly, FE production was completely uncharted territory at the time this thesis was conceived; hence the idea was if the methodology for FE production does not come to fruition I have another avenue available to take my research as well as stressing the limitations of my FE production methodology. Therefore, the second aim of this thesis was to determine if children with autism can use efficiently the inner features of a face to identify a person, when only those inner features were available during the learning, primarily deploying holistic face processing.

Children with autism have some face processing deficits but are able to do holistic processing to a limited extent (Joseph and Tanaka, 2003). Not many investigators in autism research have used the inner outer face paradigm to investigate holistic face processing abilities of individuals with autism, particularly for unfamiliar faces. Joseph and Tanaka, (2003) stated that impairment in holistic processing could not be firmly established using whole-part face paradigm because when recognition judgements were based on the mouth area, performance was on a par with the matched controls but when judgements were based on information from the eye area, performance was significantly worse. Whole-part paradigm does not seem to be the most effective tool for investigating holistic processing in individuals with autism as it presents conflicting results; children with autism may either be perceived to be inefficient or super efficient in holistic processing. Rondan et al., (2003) testified that, for matching faces, children with autism use inner and outer face information equally but this does not clarify if the inner features are processed by the autism population in isolation, in identity recognition tasks as opposed to matching tasks.

The inner/outer paradigm has been used with success for familiar faces (Wilson et al., 2007) and we decided to use it with unfamiliar faces.

One of the questions that we investigated was the ability of ASC population of using inner feature for learning and recognition when they are the only ones available.

Since only the inner face has not been presented in the learning phase to children with autism to our knowledge, as stated, the second aim was to investigate FR in children with autism when they have only inner face during learning.

8.3 Holistic processing with only inner face

None of the studies using inner outer face paradigm for TD has to our knowledge presented only inner face during the learning phase. All the studies presented full face in the learning or encoding stage and the inner or outer face was presented only during the test phase except Turati et al., (2006). It is possible, as observed for neonates (Turati et al., 2006), that children will have no problem in learing and recognising face from inner features. Only changes, i.e. adding or removing features between the learning and the test phase will prevent recognition. The aim of our studies was to investigate if children can recognise faces when only inner features are available during learning phase.

We will investigate this ability first in a control population before assessing it in an ASD population. Also, progressive lowering of the reported age of fully accomplished holistic processing ability (as demonstrated in Chapter 7) underlies the justification in looking towards an even earlier inception. Hence, one of the aims of the thesis was to investigate FR for identity, when children have only the inner face available during the learning phase at an early age of 5 years onwards.

Chapter 9

Inner and outer face effects in typically developing children and children with autism: a series of investigations.

9.1 Study 1

9.1.1 Aims of experiment 1

Children rely more on outer-face information for recognition of unfamiliar faces (Want et al. 2003; Bonner and Burton, 2004) and then at a certain age process inner face information relatively more. The main issues to be considered in this part of the thesis are as follows:

1. To investigate the effect on identity recognition when only inner face information is available in the learning phase.
2. To investigate if holistic processing ability is fully accomplished at 5 years of age.

9.1.2 Hypotheses

1. The first prediction was that, as usually observed, older children will be significantly better than younger children in all conditions.
2. The second prediction was that younger children, when presented with inner face for learning and recognition, accuracy for recognition will be as good as the recognition when full face is presented in the learning phase. This is based on the finding of Turati et al., (2006) from infant research.
3. The third and final prediction was that older children will be significantly better at full to inner face recognition. This was based on findings of Want et al., (2003) which reported accuracy of full to inner recognition in 9-year-olds to be at the same level as adults.

Inner to full face condition was the exploratory part of this experiment and so it is difficult to predict the result of that section.

9.1.3 Method

9.1.3.1 Participants

Typically developing children of three age groups, 5-6-year-olds, 8-8-year-olds and 9-10-year-olds, participated in the study. There were twenty one children in each group. All participants were tested at their school in a quiet environment. Information and consent forms were sent to parents and only when parents actually sent an affirmative consent form back was the child tested. The purpose of the work and actual task was explained to each child before seeking assent to participate in the experiment.

9.1.3.2 Apparatus and material

The face images were acquired and edited using Adobe Photo Shop version 8.0 so as to remove any distinguishing marks, ear-rings etc. Thirty faces were cropped at the top of the neck and cut precisely around the face including the hair line such that only face and hair line was left in the image. Each image was 300X300 pixels. The same thirty faces and twenty more faces were also cropped differently so as to leave only the inner features of the face. Thus finally there were three groups of faces, group one with ten inner faces matched to ten other inner faces all general features matched; group two with ten full faces and then just their inner face of these full faces matched to ten other inner faces for all general features and group three with ten inner faces where their full faces were matched to ten other full faces for hair as well as general internal features (see figure 9.1).

The computer program Dev Lab version 2005 was used to design the experiment and present stimuli to participants. The stimuli were divided into three lists resulting in three experimental conditions.

Full to inner face condition – Full face for learning and inner face for recognition

Inner to full face condition – Inner face for learning and full face for recognition

Inner to inner face condition – Inner face both for learning and recognition

Figure 9.1: Examples of the three groups of stimuli used in experiment 1

Full to inner face condition: The participant learnt full face and had to recognize the face from a pair of inner faces in the test phase. There were 10 trials.

Inner to full face condition: The participant learnt inner face and had to recognise the face from a pair of full faces. There were 10 trials.

Inner to inner face condition: The participant learnt inner face and had to recognise the face from a pair of inner faces. There were 10 trails.

9.1.3.3 Procedure

Each participant was instructed individually that "a picture will come here (experimenter pointed at the top of the screen) and will go away immediately then two pictures will come here (experimenter pointed at the bottom part of the computer screen). One of these pictures (experimenter still pointing at the bottom of the screen) will be the same as you saw at the top. It is your job to decide which one you saw up here (Experimenter pointing at the top of the screen). If you think it is this one (experimenter pointing at the bottom left of the screen) then press 'Z' and if you think it is this one (experimenter pointing at the bottom right of the screen) then press 'M'". The image on the top of the screen appeared for 1000ms followed by blank screen for 500ms and then test phase images appeared at the bottom of the screen. Test phase images remained on the screen till a response was made by the participant. Once a response was made next face stimuli appeared after 500 ms interstimulus interval.

It should be noted here that the initial stage of presenting faces at the top of the screen will be referred to as 'learning phase' and the later stage of presenting two faces at the bottom of the screen will be referred to as 'recognition or testing phase', for the purpose of this thesis.

A practice trial with images of toys was delivered first, which had to be completed successfully in order to take part in the FR task. The 'toy condition' had 6 trials where a picture of one toy appeared at the top of screen and then same image along with a distracter appeared at the bottom of screen and task was to press 'Z' or 'M' depending on which toy they had seen in the learning phase.

Once the toy condition was completed successfully, the participant was presented with the FR task and each condition was presented in a pseudo random order. Participants were expected to complete all the three conditions inner to inner, full to inner and inner to full without any break in between.

9.1.3.4 Results

The 'toy condition' was performed by each participant at 100 % accuracy level. This was not analysed any further.

Mean accuracy for the FR tasks increased with age for full to inner face condition and inner to inner face condition but stayed steady for inner to full face condition (See Table 9.1).

Table 9.1: Mean percent accuracy for three age groups for all three conditions

Face condition	5-6 years		8-8 years		9-10 years	
	Mean %	sd	Mean %	sd	Mean %	sd
Full to Inner face	65.2	19.90	83.8	12.03	81.9	13.28
Inner to Full face	82.9	19.28	68.1	14.54	84.86	10.35
Inner to Inner face	80.9	16.09	88.1	10.30	90.95	9.43

A 3 (age) X 3 (face) mixed ANOVA was conducted. The effect of age was significant (F (2, 60) = 4.34, p = 0.018). The effect of the face condition was also significant (F (1, 60) = 32.48, p = 0.001). The interaction between age and face condition was not significant (F (2, 60) = 0.86, p = 0.46).

The main effect of age was further analysed using independent sample t-tests. 5-6-year-olds were not significantly different to 8-8-year-olds in any face conditions (t = 1.68, p = 0.09; t = 1.08, p = 0.28; t = 1.41, p = 0.16 for 3 face conditions). 8-8-year-olds were significantly different to 9-10-year-olds both for full to inner (t = 2.08, p =0.04) and inner to full face (t = 1.95, p =0.05) condition but not for the inner to inner face (t = 1.15, p = 0.25) condition. 5-6-year-olds were also significantly different to 9-10-year-olds, in full to inner face (t = 3.19, p = 0.003) and inner to inner face (t = 2.45, p = 0.018) condition but not significant for inner to full face condition (t = 0.39, p =0.69).

The main effect of the face condition was further analysed using paired sample t-test. 5-6-year-olds performed significantly better in inner to inner face condition compared to full to inner face condition (t = 3.53, p= 0.002). Other face conditions for this age group were not significantly different i.e. comparison between full to inner and inner to full (t = 2.01, p= 0.058); inner to full and inner to inner (t = 2.05, p = 0.053). 8-8-year-olds were significantly better in inner to inner face condition compared to full to inner (t = 3.83, p = 0.001) and inner to full (t = 5.04, p = 0.001). There was no difference between full to inner and inner to full face conditions within group (t = 1.06, p = 0.125). 9-10-year-olds were significantly better in inner to inner face condition compared to full to inner (t = 2.52, p = 0.02) and inner to full (t = 6.39, p = 0.001). The full to inner face condition was in turn significantly better compared to inner to full face condition (t = 2.3, p =0.03).

This shows that 9-10-year-olds were significantly better than the two younger age groups but there was no significant difference between the two younger groups. Performance or all children was exemplary for the inner to inner face condition. They had no problem processing inner face when inner face was available in isolation both for learning and recognition. All children were relatively poor at recognising full face after seeing only inner face and the performance for this did not improve with age.

5-6-year-olds performed equally for full to inner and inner to full face conditions however, performance for inner to inner face condition was significantly better than full to inner face condition. They were significantly worse than 9-10-year-olds in recognising inner face both from full face and from inner face only information.

8-8-year-olds performed equally for full to inner and inner to full face conditions. However, performance for inner to inner face condition was significantly better than both the other conditions. They were significantly worse than 9-10-year-olds in recognising full face from inner face and inner face from full face.

9-10-year-olds performed significantly better in the inner to inner face condition compared to the two other conditions and full to inner was in turn significantly better than inner to full face condition within group. As stated earlier, both younger age groups were significantly worse than this age group.

9.1.3.5 Discussion

Older children, particularly 9-10-year-olds were significantly better than both the younger age groups in some of the face conditions tested, which partially meets the first hypothesis. Overall all children were excellent in recognising faces from inner face only information and the youngest group were significantly worse than the oldest group for this face condition. For inner to inner face recognition 8-8-year-olds were not different to either group. This is a new finding as previous research never presented inner face only during learning to children aged 5-10 years. Turati et al., (2006) had presented similar stimuli to infants and the study reported that infants successfully discriminated inner faces. Based on that data a prediction was made that if infants are able to process inner face without any difficulty children will be able to do the same and thus performance for this will be at least similar to full to inner face. However, performance for inner to inner was significantly better than full to inner for all age groups hence this prediction did not come true. The research presented in this thesis extends the findings of infant research to typically developing children 5-10 years of age.

The full to inner face condition where children learn the full face and recognise the same face from inner face only, produced results similar to those existing in the literature (Want et al., 2003; Bonner and Burton, 2004). It is in line with the third prediction and meets the hypothesis. In Want et al., (2003) participants were provided with 3 second long videos of full face during learning followed by inner face. The accuracy reported in that study is very similar to those reported in this study. For instance, 8-year-olds were 81% and 9-year-olds were 89% accurate (Want et al., 2003) compared to 83% and 81% for the two age groups in the present study. It can be concluded that even very brief exposure to unfamiliar faces under experimental conditions is sufficient for testing FR ability in children. There has been evidence of progressive lowering of the reported age for fully accomplished holistic processing ability (De Herring et al., 2008; Mondloch et al., 2002; Carey and Diamond, 1994). One of the underlying justifications of this experiment was to look towards an even earlier inception, the prediction should have perhaps been two tailed on the balance rather than directional prediction. So, an easy conclusion to draw from this would be that children as young as five years of age do process faces holistically and can process inner face when only inner face is available during learning.

The accuracy for the inner to full face condition result was the lowest for all three age groups and performance for this face condition did not improve at all. This is a new finding as in previous research inner face during learning and full face for recognition has not been presented. This was the exploratory part of the research hence there was no prediction. It is this third finding that does not allow simple conclusions made previously on holistic face processing because when children of all three age groups had only inner face during learning and full face for recognition the performance rose from 82% to only 84%. To add to this, there was a significant dip at 8-8 years of age when identity judgements are based on full face having seen inner face only at the learning phase. This finding questions the proficiency in holistic processing in older children. If children as old as 6 years are deemed to have mature holistic processing and perform at the same level as adults (Mondloch et al., 2008), then 10-year-olds in this experiment should be have been able to improve performance for inner to full face condition steadily just like the other two conditions.

In summary, 9-10-year-olds were significantly better than 5-6-year-olds in the full to inner face condition, providing conformation of a developmental trend for holistic face processing which is in line with Want et al., (2003); Bonner and Burton, (2003); Mondloch et al., (2008). In addition, my data also shows that inner facial features alone convey sufficient information to operate holistic face processing, even at the age of five. This provides conformation of progressive lowering of age for holistic face processing, which is in line with De Heering et al., (2008). Yet evidence gathered in this experiment raises 2 different issues, which need to be addressed. First, as noted, although accuracy was reasonably good (82% at age of 5 years) when only inner face was presented for learning followed by full face for recognition, it did not increase with age. On the contrary, there was a dip at the age of 8-8 years of age and then marginal increase bringing 9-10-year-olds at same level as 5-year-olds. Secondly, accuracy when only inner face was available for learning and recognition performance was exceptionally good for all three age groups.

This apparent discrepancy between the experiment reported here and previous ones can be explained by highlighting a methodological fact stated by Turati et al., (2006). In the inner to inner face condition the learning stimuli and recognition stimuli were exactly the same along with a distracter. In all the previous studies participants were asked to recognise inner or outer face having learnt the face in its entirety. Turati et al., (2006) state that infant studies such as Pascalis et al., (1995) and Bartrip et al., (2001) revealed newborns' failure to accomplish a more demanding task, namely the detection of the perceptual invariance between two appearances of the same face, the mother's face with and without hair. Turati et al., (2006) asserted that any alteration in the perceptual appearance of a face, produced either by removal or addition of specific feature would affect recognition. Extending this argument to the findings of this experiment, it can be concluded that an alteration in perceptual appearance was caused when full or inner faces were presented alternatively during learning and recognition. This continues to hamper accuracy in recognition task, even at the age of 10. Hence, like the infants in Turati et al., (2006) children 5-10 years of age had no problem recognising faces from inner face information only when there was no perceptual alteration but the recognition accuracy suffered when there was perceptual alteration.

A second explanation could be that holistic face processing does not only mean glueing inner facial features together, but also glueing the inner face to external contours, making it difficult to recognise internal features presented in different contours (Sinha and Poggio, 1996; Young et al., 1988; Maurer et al., 2002) as the same face. This may have caused the poor recognition in the inner to full face condition reported here and will be discussed in detail under general discussion.

Perceptual similarity (Turati et al., 2006) and both aspects of holistic face processing (glueing inner facial features together as well as glueing inner face with external contour) can explain the data presented in this experiment. Not only have the two older groups demonstrated holistic face processing but children as young as five have also demonstrated holistic face processing in this experiment. Juxtaposing the data from this experiment with previous research (Mondloch et al., 2008; De Heering et al., 2008) we can perhaps assume that both aspects of holistic processing are functioning at the age of five.

Finally, data gathered in experiment 1 poses the intriguing question, whether the children in inner to inner face condition relied on local feature matching or actually executed holistic processing. In order to resolve this question it seemed logical to investigate featural processing or holistic processing operating when inner face is presented both during learning and recognition condition. An inversion effect can be used to examine holistic processing (Maurer et al., 2002), hence experiment 2 was designed to investigate this.

9.2 Experiment 2

Identity recognition, specifically in an inner to inner face condition, can be argued to be completely based on featural processing, whereby children are only matching one specific feature of the face. In order to investigate if participants are actually matching features for face recognition in the inner to inner face condition or using holistic face processing, experiment 2 was carried out as a control experiment.

9.2.1 Aim of the experiment

1. To investigate if children use featural processing when only inner face is presented during both learning and recognition phases.

9.2.2 Hypotheses

The prediction was that FR for upright inner faces will be significantly better than FR for inverted inner faces for all age groups.

9.2.3 Method

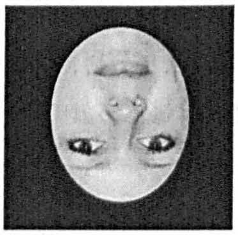
9.2.3.1 Participants

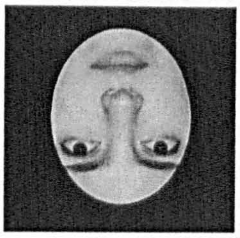
Typically developing children of three age groups, 5-6-year-olds, 8-8-year-olds and 9-10-year-olds participated in the study. There were twenty three children in each group. All the conditions of experiment 1 were applied for testing.

9.2.3.2 Apparatus and material

Fifteen colour photographs each of male and female faces were taken from the data base of face lab and matched to thirty other faces from the data base for hair and eye colour and general feature similarity. All of these images were then edited using Adobe Photo Shop version 8.0. Each image was imported into Photo shop, any distinguishing marks, ear-rings etc. were removed. All faces were cropped to leave only inner features in the image.

Face stimulus for learning





Face stimuli for recognition

Figure 9.2: Examples of faces presented for inversion effect investigation

The image size was 300X300 pixels. Finally we had sixty inner faces, thirty pairs matched for general feature similarity (see figure 9.2).

The same computer program was used to design the experiment and present stimuli to participants. Two lists each of 15 photos one upright and one inverted was to be given to participants in a pseudorandom order.

9.2.3.2 Procedure

The procedure was exactly same as the experiment 1 first a trial toy condition and then the FR task was administered. In half of the trials the recognition test was done on upright faces and on the other half on inverted faces.

The image on the top of the screen appeared for 1000ms followed by blank screen for 500ms and then test phase images appeared at the bottom of the screen. Test phase images remained on the screen till a response was made by the participant. Once a response was made next face stimuli appeared after 500 ms interstimulus interval.

9.2.3.3 Results

All participants performed at 100% accuracy level for the toy condition and this was not analysed any further. Table 9.2 shows mean accuracy for three age groups.

Table 9.2: Mean percent accuracy for three age groups

Face condition	5-6 years		8-8 years		9-10 years	
	Mean %	sd	Mean %	sd	Mean %	sd
Upright face	89.86	8.59	90.89	6.49	91.13	8.98
Inverted face	81.43	8.34	80.89	11.05	69.84	11.48

A 3x2 split-plot ANOVA was conducted on the accuracy scores of three age groups. The main effect of the face condition was significant ($F = 222.85$, $p = 0.001$), main effect of age was not significant, ($F = 0.01$, $p = 0.9$) and interaction was not significant ($F = 0.38$, $p = 0.68$). As the age groups were not significantly different to each other, data was collapsed to just one group and paired comparison of means revealed that mean accuracy for the upright face trials was significantly different to the inverted face trials in a two-tailed t test, $t = 15.08$, $p = 0.001$. All children were better at recognising upright faces compared to inverted faces.

9.2.3.4 Discussion

The purpose of this experiment was to examine if children 5-10 years of age use featural processing when presented with inner face during learning and recognition phases. The results clearly demonstrate that all age groups were sensitive to the 'inversion effect' whereby performance for upright faces were significantly better than for inverted faces. The tendency to use holistic face processing is very strong by the age of 5, whereby even when only the inner face is available for learning and recognition, featural processing is not used.

This finding reinforces the conclusions of experiment 1: 5-10-year-olds can process inner face when only inner face is available. Previously seen inner face when presented within novel external contour accuracy deteriorates because of holistic processing.

The next step would be to examine children's behaviour for FR when both full and inner faces are available for learning. Which one would children process better and recognise easily? Before embarking in that direction, children with autism were tested for holistic face processing, more specifically for inner face processing. The main focus of this research was FE production in children with autism. For this it was vital to examine if children with autism process inner faces. The literature for this is very mixed as presented in chapter 6. It was imperative that the autism sample taking part in FE production study were able to process inner faces. This is the main rationale for the experiment 3.

9.3 Experiment 3

Experiment 1 and 2 established that typically developing children can process inner faces exclusively for identity recognition and use a holistic face processing strategy when only inner face features are available for learning. The second significant finding was that holistic face processing glueing the inner face and external contours makes it difficult to recognise the inner face previously seen in isolation.

Holistic face processing in an autism population has been investigated mainly using whole-part paradigm or inner outer face matching tasks. The inner outer FR paradigm has only been used by Wilson et al., (in press) with low-functioning children with autism. Moreover, only inner face during learning has not been reported to be part of the design in any research with an autism sample. Hence the main aims of the experiment were as follows:

9.3.1 Aims of experiment 3

1. To examine the effect of 'only inner face' on learning and subsequent recognition either from full face or from the same inner face.
2. To determine if holistic face processing is significantly different in children with autism in comparison to a control sample matched on one to one basis for IQ and Chronological age.

These were actually the second aims of the thesis as I mentioned in Chapter 8.

9.3.2 Hypotheses

1. The first prediction was that children with autism will not be significantly different to TD in identity recognition. This is based on the literature where older children, adults and high functioning individuals with autism generally have been reported to have the same accuracy level as TD even when the strategy used is atypical.
2. The second prediction was that children with autism will be better than TD in the inner to full face condition particularly because the autism population is known for local level processing and avoiding global processing so the external contour will not hamper identity recognition to the same extent as for TD.
3. The third and final prediction would then be that the autism sample will not be as efficient in holistic face processing as TD.

9.3.3 Method

9.3.3.1 Participants

Seventeen children with autism aged 9-15 years matched individually for both age and IQ to seventeen typically developing children were tested (see Table 9.3) Chapter 6 gives a detailed account of recruitment, inclusion and exclusion criteria and matching groups. Actual age, full scale IQ, verbal IQ and performance IQ of each HFA and MC participant is attached in appendix 5.

Table 9.3: Mean age and IQ for HFA and matched control sample

	Mean Age	Mean FSIQ	Mean VIQ	Mean PIQ
Matched controls (MC)	12.98	106.11	104.94	106.11
HFA sample	13.11	105.94	106.11	104.64

9.3.3.2 Apparatus and material

The Wechsler Abbreviated Scale of Intelligence (WASI) was used to measure verbal, non-verbal and full scale IQ for all participants.

The Autism diagnostic interview – revised (ADI-R) was used for the semi-structured interview with parents of children with autism.

Other apparatus and material of experiment 1 was used for the actual inner-outer face study.

9.3.3.3 Procedure

The same procedure as in experiment 1 was followed for the FR task both for children with autism and TD.

Each child with autism was first asked to complete inner-outer face paradigm task. Once the computer task was successfully completed by the participant then WASI was administered individually by me at a separate appointment in a quiet area at the participant's school, which was scored to get verbal, non-verbal and full scale IQ score.

Typically developing children were then recruited, administered WASI individually by me in a quiet area at the participant's school and if the IQ matched to a participant along with chronological age then they were further tested.

9.3.3.4 Results

There was no significant difference between the HFA and MC groups on matching criteria of age ($t = 0.268$, $p= 0.891$) and IQ ($t = 0.04$, $p = 0.969$).

All participants performed at 100% accuracy level for the toy condition and this was not analysed any further. On the whole, both ASC and TD sample were above 80% accurate in FR. Table 9.4 shows the mean percentage accuracy of both the groups for all three face conditions.

Table 9.4: Mean percent accuracy of HFA and MC for three face conditions.

Face condition	HFA		MC	
	Mean %	sd	Mean %	sd
Full to inner face	88.65	13.48	81.18	10.53
Inner to full face	89.41	10.29	82.35	13.01
Inner to Inner face	92.35	16.01	95.88	8.12

A 3x2 split plot ANOVA was conducted. The face condition effect was significant ($F(1, 32) = 22.86$, $p = 0.001$). The group effect was not significant ($F(1, 32) = 1.18$, $p = 0.28$). The interaction between group and face condition was also not significant ($F(2, 32) = 0.1$, $p = 0.9$). As the difference between HFA and MC sample was not significant the data of the two groups were collapsed as one group for further investigation of the face condition differences.

A paired sample t-test was carried out and mean accuracy for full to inner face was not significantly different to mean accuracy for inner to full face condition ($t = 0.62$, $p= 0.53$). The mean accuracy for inner to inner face condition was significantly better than inner to full face ($t = 4.68$, $p=0.001$) and inner to inner face condition was also significantly better than full to inner face ($t = 8.15$, $p = 0.001$).

9.3.3.5 Correlation between IQ and production scores

Literature in the past has explored the correlation between CARS score and performance on face processing tasks (Riby et al., 2008) in order to investigate if the level of functioning on the autism spectrum has an impact on level of performance. In this thesis correlation between level of performance and IQ was investigated because the CARS score may not have been very reliable. As stated in chapter 6 the CARS questionnaire was completed by teachers or parents. As this scoring was not monitored by researchers of this experiment it is extremely difficult to estimate how the pre-existing diagnosis affected the perception of person answering the questionnaire. Taking such bias due to previous knowledge and information into consideration it was decided to investigate the correlation with IQ. None of the correlation was significant (See appendix 6).

9.3.4 Discussion

To my knowledge previous researches have not presented inner face in learning phase to children with autism.

Children with autism were not significantly different to TD which is in line with the first prediction. This is also in line with findings of a section of previous research testing children with autism but focussing on mouth region (Joseph and Tanaka, 2003), adults with autism for holistic processing (Behrmann et al., 2006), for accuracy in face matching (Rondan et al., 2003) and FR using either outer or inner face during testing (Wilson et al., in press). Closer inspection of percentage accuracy reveals that TD were marginally better than HFA in identity recognition for all three conditions, nonetheless these differences were not significant. It can be concluded that there was no difference between HFA sample and age and IQ matched controls for FR using inner-outer face paradigm.

The second prediction was that children with autism will be better than the TD particularly in the inner to full face condition because, autism population is known for superior local level processing ability (Mottron et al., 2006) and avoid global processing so the external contour will not hamper identity recognition to the same extent as the TD. HFA sample were as affected as the TD in the inner to full face condition; meaning the accuracy for inner to full face was significantly worse than the inner to inner face condition leading to the rejection second prediction. The autism sample appear to be operating holistic face processing whereby the inner face was glued to external contour making the previously seen inner face appear to be a novel face.

The third and final prediction was that the autism sample will not be as efficient in holistic face processing as TD. Based on the finding for all three face conditions it is clear that children with autism were no different than the TD and thus the final prediction also had to be rejected.

This means that the HFA sample can, just like the TD, process inner face information when only inner face information is available both during learning and testing. In fact, the recognition accuracy demonstrates that when only inner face information was available the accuracy performance was best, which is in line with experiment 1 reported here. The findings of this experiment allow me to extend the possible explanations given for children aged 5-10 years to children with autism. It appears that alteration in perceptual appearance continues to hamper identity recognition in the HFA sample just like 5-10-year-olds in experiment 1 and infants in experiment reported by Turati et al., (2006). It is also evident that the HFA sample executes a holistic face processing strategy, which enhances the FR for inner face in isolation and deteriorates FR of inner face when presented with novel external contour.

It has been demonstrated that the HFA sample can process inner faces and that they process such stimuli holistically. They can thus be tested for the FE production experiment which will be presented under chapter 11. The final investigation in the holistic processing is examining if children are presented with both full and inner face which they will process better.

9.3.5 Limitation of experiment 3

Face processing studies in the recent past have used techniques such as reaction time or eye tracking in order to investigate if the autism samples are achieving the same task in more time (Behrmann et al., 2006) or by using an entirely different strategy (Rondan and Deruelle, 2008). Although, using eye tracking was beyond the remit of this thesis, reaction time could have been monitored, recorded and analysed. Since the participants in experiment 1 and 2 were not told that their reaction time was recorded, it was decided that the same approach would be adopted for experiment 3. Nonetheless, on retrospective analysis of data and reflection it appears that this may actually be a limitation of this experiment, whereby opportunities to further explore any difference in holistic face processing within the present design was lost.

9.4 Experiment 4

As I move on to exploring FE production in the HFA sample the one last question to address in this area using either inner or outer face was: What do TD do if they have both full and inner face available for learning and then at recognition? Which one would they prefer?

It should be noted here that familiar and unfamiliar faces are processed differently by adults, who rely initially more on outer face parts for recognition and slowly switch to inner face processing as the face gets more familiar (Bonner et al., 2003). In the case of children, Want et al., (2003) demonstrated and Bonner and Burton, (2004) reiterated that children as young as nine and seven respectively, process unfamiliar faces holistically in a manner that is similar to adults, where the inner and outer face information are used equally but the judgements based on outer face parts are more efficient.

So if children learn both full face and inner only face the investigation was will this help them in using the inner features for recognition?

9.4.1 Aim of the experiment

To explore when both full and inner face are available for learning which one do children use more effectively.

The second was to record reaction time, in order to address one of the flaws of previous experiment and to explore the difference HFA and TD group performance both in accuracy and speed.

9.4.2 Hypotheses

1. My first prediction was that older children will be significantly more accurate younger children in the identity recognition task.

2. The second prediction was that recognition for full face and inner face will be equivalent. This was based on the hypothesis presented by Turati et al., (2006) that perceptual similarity enhances accuracy levels.
3. My final prediction was that older children will be significantly faster than the younger children.

9.4.3 Method

9.4.3.1 Participants

Typically developing children of three age groups, 5-6-year-olds, 8-8-year-olds and 9-10-year-olds participated in the study. There were twenty three children in each group. All the conditions of experiment 1 were applied for testing.

9.4.3.2 Apparatus and material

Female and male adults were filmed individually using digital camcorder. Before the filming started the protagonist was asked to wear a black hooded jacket to achieve uniform clothing and the hood was needed later in the recording. The protagonist began by facing the camera and then moved his head by 90 degrees to face away from the camera so that the face now appeared in a profile shot. He then moved his head slowly from his left shoulder to right shoulder i.e. moving head by 180 degree and then came back to the resting position so that the camera had the full frontal face in view. As he moved the head he spoke the following phrase "Baba black sheep have you any wool" in order to introduce motion in the internal features of the face. Once back in the resting position he put the hood on such that only the inner face was visible now and all the hair as well as the hairline was covered. He then once again moved his head from full frontal view of the face to the left side by 90 degrees for the face to appear in profile shot. This time when he started to move the head by 180 degrees and finally come back to the resting position (front facing the camera) he said "yes sir, yes sir three bags full". Thirty film clips were edited to make them 10 seconds long and sound was removed. Portrait photographs of adults from the film were extracted and matched for general similarity with 30 novel adult faces. These photos were then edited using Photoshop and cropped. Fifteen photos were cropped to show the full face and nothing else and fifteen were cut in an oval such that the oval had the inner face only

The computer program Dev Lab 2005 version was used to design the experiment and present stimuli to participants. This program showed the 10s recording at the top of the screen and after a delay of 500 ms when the screen was blank, showed a pair of faces side by side at the bottom of screen. The stimuli were divided into two lists both had fifteen randomised trials of a video followed by either pairs of full faces or pairs of inner faces.

9.4.3.3 Procedure

It was exactly same as experiment 1, although participants were informed that they will be watching a short video and urged not to get distracted but to keep looking at the screen.

9.4.3.4Results

The mean accuracy for full and inner face conditions increased with age (see table 9.5) with 9-10-year-olds reaching the ceiling limit of accuracy.

Table 9.5: Mean percentage accuracy for full and inner face

Age groups	Mean% accuracy for full face	Mean % accuracy for inner face	T test for difference between two face conditions (t=)	P
5-6 years	80.95	66.11	4.56	0.001
8-8 years	88.55	83.95	5.34	0.001
9-10 years	93.88	84.03	4.65	0.001

A 3x2 split plot ANOVA was conducted for age and face conditions. The main effect of age was significant ($F = 10.81$, $p = 0.001$), and the main effect of face condition was also significant ($F = 68.94$, $p = 0.001$), but the interaction between the two factors was not significant ($F = 0.99$, $p = 0.38$).

The main effect of age was further analysed using independent sample t-test, which revealed 5-6-year-olds were not significantly different to 8-8-year-olds ($t = 1.85$, $p = 0.08$) for full face or for inner face ($t = 1.58$, $p = 0.123$). The difference between 8-8-year-olds and 9-10-year-olds was significant ($t = 2.25$, $p = 0.03$) for full face and for inner face conditions ($t = 2.4$, $p = 0.02$). 5-6-year-olds were also significantly worse than 9-10-year-olds ($t= 4.06$, $p = 0.001$) for full face and for inner face ($t= 4.62$, $p = 0.001$).

The main effect of the face condition was further analysed using paired sample t-test which revealed that for all age groups full face recognition was significantly better than inner face recognition (See table 9.5).

The reaction time was recorded and this information shows that mean reaction time decreased with age (See table 9.6).

Table 9.6: Mean reaction time of all age groups for two face conditions

	Full face recognition (msec)	Inner face recognition (msec)
5-6 years	3943.62	3590.38
8-8 years	2514.05	2548.05
9-10 years	1848.84	1982.86

A 3x2 split plot ANOVA was conducted for age and mean reaction time. The main effect of age was significant ($F = 32.23$, $p = 0.001$), and the main effect of face condition was not significant ($F = 3.28$, $p = 0.08$) and the interaction not was significant. ($F=.361$, $p = 0.69$). Since the reaction time for full and inner face condition were not significantly different both the data sets were collapsed and the main effect of age was further analysed using independent sample t-test, which revealed that 5-6-year-olds were significantly slower than 8-8-year-olds ($t = 4.36$, $p = 0.001$) and they in turn were significantly slower than 9-10-year-olds ($t = 2.93$, $p = 0.006$).

9.4.4 Discussion

The aim of experiment 4 was to explore when both full and inner faces are available during learning, which one children use more effectively, taking both speed and accuracy measures into consideration.

9-10-year-olds were significantly better than both the younger age groups indicating that the first prediction was true. This was in line with previous research (Want et al., 2003; Bonner and Burton, 2004).

There was a significant difference between full and inner FR for each age group: all the children were better at recognising faces from full face in comparison to inner face. Thus recognition of full face was well above chance at 80% to start with and it increased to 93 % for 9 to 10 year olds reaching almost ceiling limits. The 9 to 10 year olds were significantly different to 8 to 8 year olds but 5 to 6 year olds were not significantly different to 8 to 8 year olds so even though children are better at recognising faces from full face this does not improve significantly with age.

All participants were significantly better in full FR compared to inner FR, thus rejecting second prediction. This was based on the argument presented by Turati et al., (2006) regarding perceptual similarity. Although the stimuli used for learning and recognition were such that perceptual similarity is maintained, it did not achieve the same results. Children in general recognised full face better and preferred to learn a face from the full face rather than the inner face. It can be concluded that children can process inner face when this is the only information available such as condition 3 in experiment 1, however if they have full face available they prefer to use this instead.

The reaction time data indicates that younger children are significantly slower than the older children. The reaction time performance emphasised that even when 5–year-olds perform at 80 % level which is very good; it was achieved in significantly longer time. So holistic face processing does exist from the age of five years but in a sense it is still developing because as the child matures the efficiency improves remarkably, allowing ten-year-olds to perform the same task significantly faster.

Exploratory examinations performed to investigate the novel components previously unexplored from developmental perspectives; (namely the effect of both full and inner face being available for learning) exposed numerous issues. Firstly, it can be concluded that when both full and inner face information is available for learning, holistic face processing task can be achieved by children as young as 5 quite easily for full face leading to accurate judgement 80 % of the time. Secondly, even when inner face is available for learning it is not used as efficiently as the full face information resulting in, 66 % accuracy in 5-6-year-olds which is very similar to 8-8-year-olds (83 % accurate). It was only the 9-10-year- olds that were significantly different to both the younger groups with accuracy level of 84 %. Accuracy for FR rises showing that finally by the age of 9 years children can make effective judgements from only inner face. However, this accuracy level is not as good as when judgements are made from full face. Thirdly, the reaction time results highlight that children do not spend any more time in recognising inner face in comparison to full face. These findings are in line with Want et al., (2003) and Bonner and Burton, (2004) whereby children process unfamiliar faces holistically. Both inner and outer face information can be used, but the judgements based on outer face parts are more efficient and more accurate. Younger children may be using holistic face processing but they still do not seem to have reached the level of adult expertise and there is a speed accuracy trade off between full face and inner face recognition.

9.5 General discussions

The aim of the series of experiments reported here was to investigate the effect on face recognition when only the inner face is presented to children as young as 6 year olds. Children aged 6-10-year-olds were significantly better at recognising an inner face which was originally learnt as a whole face. The performance of 10-year-olds was significantly better than 6-year-olds which highlights that face processing is affected by both maturational factors as well as qualitative factors. Research in face recognition clearly indicates that children process unfamiliar faces differently to adults. One of the main aims of this thesis was to examine holistic face processing in children using the inner outer face recognition paradigm. It can be concluded that children process faces as a whole and the findings of the experiments reported here substantiates this. The susceptibility to perceive faces as a whole is so strong that when participants were presented with a previously seen inner face within a novel contour it was perceived as a new face. This has been reported previously elsewhere (Sinha and Poggio, 1996; Young et al., 1988) and Campbell et al. (1999) reported that even blurring of the outer face contour draws attention and cannot be ignored.

Experiments 2 and 3 reported here investigated the effect on face recognition when only the inner face is available for learning. Children aged 6 to 10 years of age were sensitive to the 'inversion effect' with only the inner face. One explanation may be that the inner face was processed holistically rather than piecemeal processing. However, when both the inner and the whole face were available participants were faster in recognising the whole face and accuracy for the whole face was significantly better. Since the inner face has not been presented previously in the learning phase the only parsimonious conclusion I draw from this finding is that children process the inner face if they have to but their performance for recognition is better when the whole face is available for learning. The findings of these experiments fit well with the experience-expectant theory which claims that experience is essential for face expertise to develop. It appears from the findings reported here that experience with the full face definitely enhances recognition performance for full face stimuli. Since in day to day life children are not exposed to just the inner face in Britain perhaps recognition of the inner face takes longer and is not as accurate.

HFA participants were as good as matched controls in face processing when the inner or the full face were presented during learning and testing. It can be concluded that HFA participants were as susceptible to holistic processing as MC. The neural system model for face perception (Haxby et al., 2000) clearly states that lateral fusiform gyrus is responsible for identity recognition. Juxtaposing the finding of the experiment reported here with this model one inference may be that in the HFA sample the lateral fusiform gyrus is functioning and so the face processing deficit in HFA is the result of a more downstream insult. However, previous researchers have reliably demonstrated that autism population can develop alternative strategies to process faces (Behrmann et al., 2006). Thus an alternative explanation could be that HFA sample even with atypical lateral fusiform gyrus can perform at levels similar to MC by developing alternative strategies.

Chapter 10

Production of FE on demand and with context in two age groups: a series of investigation

10.1 Introduction: Production of facial expression

To date there has been no generally accepted theory of emotion processing, or any generally accepted theoretical framework with which to understand the development of emotion processing and associated neural systems (Mclure, 2000; Herba and Phillips, 2004). The processing of emotionally salient information is vital for our survival as social beings. It is comprised of physiological, experiential, cognitive, behavioural, expressive, attitudinal and regulatory components (Brody, 1985). Chapter 3 covers the processes important in understanding emotional experiences (Phillips et al., 2003) and outlines that FE is a very small part of the whole complex system, but one that has received a lot of attention. This is primarily because probing into other domains, such as discrimination of body postures or prosody in voice, involves many more confounding factors, including verbal and physical ability (Herba and Phillips, 2004). Even within the field of FE most studies have focussed on identification, discrimination or labelling while there has been little research on actual production. This is because, apart from various confounding factors of recording and scoring, FEs are governed by two contradictory purposes (Blair, 2003).

One of the purposes of FE is the communication of valence; imparting specific information to the observer (Mineka and Cook, 1993; Blair, 2003; Matthew and Wells, 1999). The second purpose of FE is an automatic display of the emotional experience one is going through (Darwin, 1872; Ekman, 1997). However, empirical evidence strongly suggests that the emotions a person displays are not always what the person emotionally experiences (Camras, 1994).This is contradictory to both the purposes of FE. Societal and cultural proscriptions as to what emotion should be displayed under what circumstances and how intensely are major factors regulating the expression of emotion via FE (Blair, 2003; Ekman and Friesen, 1969). There is a suggestion that presence of an observer is one of the factors that regulates spontaneous and over learned FE as well as controlled and posed FE (Rinn, 1984). FE and emotions are multidimensional because on one hand we understand emotions to be product of emotional experience while on the other hand we understand FEs are tools to communicate. The overarching factor nullifying both the above perceptions is the 'display rules'; It is within this framework I embarked to explore FE production and emotion understanding in HFA sample; it is an avenue not previously considered, at least not to my knowledge.

Individuals with autism have impairment in social interaction, communication and imitation as stated by ICD-10 (WHO, 1994). From this understanding scientists have examined autism individuals' ability for FE recognition, discrimination and labelling.

This chapter discusses the scattered and limited evidence of FE imitation and labelling of emotions within a typically developing population, population with learning difficulties and autism.

10.1.1 FE labelling and production in MC

It is known that FE is governed by display rules. Reichenbach and Masters, (1983) scrutinised children's understanding of actual FE produced in a given context. In other words they examined whether children can label emotions when they are given a particular context in which the character of the story should feel that emotion. For example "Mary left her favourite toy at someone's house and will not get it for a long time" meant that Mary would feel sad. In this study children were read the short stories while four FE were displayed on slide; happy, sad, angry and neutral. The study reported that recognition of expressive facial expression was enhanced by the context. Happy was judged more accurately than the other four affects, but older children misjudged happy more than younger children, who judged 95 % of happy context accurately. The study also reported that anger was misjudged as sad on 38 % of occasions, making it the most misjudged emotion; this was particularly pronounced in older children. Rather than concluding that some expressions are more difficult to learn or that accuracy increases with age, experience and socialisation, the authors concluded that different expressions are conceptualised differently. The expressions are conceptualised in terms of perceptual cues as well as other ways such as the likelihood of a specific behaviour when that emotion is experienced or the feedback received from others when that emotion is expressed.

Stewart and Singh, (1995) reported a study investigating the ability of children with learning difficulties to produce FE and understanding of emotions in context. Six, 12 to 13 year olds with IQs ranging from 44 to 64 were asked to match the emotion described in a story to one of the six basic FE. Participants were then asked to show how that FE would appear on their face. For instance, "if someone gave you a present that you had always wanted, you would be glad. You would be pleased and happy" is an example of happy story; task being to pick the FE which is happy and then show the same FE on their own face. Happy expressions were the easiest to match and surprised was the hardest to match to the story condition. This study was essentially looking at improving the FE production ability via training so baseline data for production was recorded, training provided and then improvement was noted in children with learning difficulty.

Linda Camras investigated FE production in infants. For instance, Camras, Lambreht and Michel, (1996) reported that infants produced prototypical FE in situations that were not congruent with the situation. Camras et al., (2002) reported findings contrary to the previous one where infants were experiencing an emotion but not producing the congruent prototypical FE. In addition Camras, (1992) had observed considerable lability in infants FE i.e. rapid shifts between anger, pain and sad FE when crying. All of these findings taken together emphasise the influence of 'display rules' and how early children start picking up social and cultural proscriptions.

Field and Walden, (1982) investigated FE production and discrimination in typically developing children 3-5 years of age. Participants were required to produce a range of FEs as well as discriminate FEs produced. Children were best at producing happy FEs followed by angry and afraid. The study reported that children's ability to produce FE was superior than their ability discriminate FEs and that IQ scores were correlated to expressivity.

10.1.2 FE imitation in ASC

In the autism population FE production has been investigated only in toddlers and it is the imitation of FE as opposed to production that has generally been examined. This is because imitation over the first two years of life is very elaborate and serves several functions, for instance imitation of FE provides a sense of connectedness, mutuality and a means of communication with social partners (Meltzoff and Gopnik, 1993). Imitation also gives the toddler information about the physical and social world allowing social learning through imitation (Rogers et al., 2003). With autism being a social disorder, and impairment in communication and interaction being one of its cardinal features (according to ICD-10; WHO, 1994), imitation deficit has been claimed to be a fundamental to social deficit and hence empirically investigated.

Rogers et al., (2003) investigated facial imitation among various other forms of imitation such as body posture and action on objects they reported that three-year-old children with autism were significantly worse at imitation than MC.

McIntosh et al., (2006) examined implicit and explicit imitation of FE in adolescents with autism and a typically developing sample matched for age, gender and verbal intelligence. 18-30-year-old participants were asked first just to look at the pictures as they appeared and in the second task asked to explicitly copy the facial movements. The performance was recorded using electromyography (EMG) which records all the muscle movements. The expressions used were happy and angry and results showed that individuals with autism were impaired in implicit imitation but the performance of explicit imitation was same as the MC. The authors concluded that when individuals with autism are asked to copy FE they would be able to do it as successfully as MC but when they are expected to copy FE automatically they will fail the task.

10.2 Aim of experiment 1: Investigation of FE production in MC children

It has been established that FE has been researched mostly examining recognition, discrimination, matching and labelling the expressions. Labelling of emotions has been researched to a very limited extent because of the confounding factor of verbal ability. Studies which have used labelling emotion tasks have emphasised the impact of *display rules* on these tasks. It appears that children learn from a very young age that the emotions felt and FE displayed may not always be congruent. In addition, children learn that not all emotions felt ought to be displayed. Literature claims that FE production has not been investigated because of the confounding factors such as measurement and scoring; as well as the social and cultural proscriptions, attitudes and display rules that hugely impacts FE production (Herba and Phillips, 2004; Reichenbach and Masters, 1983).

Bearing all the constraints in mind, I attempted to explore FE production in high functioning children with autism (HFA) in order to investigate whether individuals with autism are able to produce FEs on demand, as in McIntosh et al's., (2006) sample, without any prompts or cues. In addition, ability to label the emotion of the character in the story was investigated. Finally, having accurately labelled an emotion, it was examined if individuals with autism are able to produce the FE that best depicts that emotion.

A task was developed to measure FE production in children. Since there is no data or information on FE production available, the first study was designed to create some baseline data underpinning the developmental trend.

10.2.1 Hypotheses

To my knowledge production of the six basic FE has not been investigated before in typically developing children beyond preschool years. The first section was an exploratory study to establish baseline data in MC hence predictions cannot be made on the ability of MC children. Intuition suggests that when context is provided children will find it easier to produce expressions. However, I cannot make such assumptions because in previous research context was not found to help children asked to label FEs (Reichenbach and Masters, 1983).

FE recognition has a developmental trend with happy being recognised the best and earliest followed by sad or angry, followed by surprise or fear and disgust emerging last. Based on this, the only prediction that can be made by extrapolation is that a

- Happy FE will be easiest to produce followed by sad or angry or fear or surprise and that disgust FE will be hardest to produce.

10.2.2 Method

10.2.2.1 Participants

Typically developing children of two age groups, 6-7-year-olds and 9-10-year-olds, twelve in each group, participated in the study. All participants were tested at their school in a quiet environment. Information and consent forms were sent to parents and only when parents actually sent an affirmative consent form back was the child tested. The purpose of the work and actual task was explained to each child before seeking assent.

10.2.2.2 Apparatus and material

- Vignettes: Eighteen stories that described the events likely to elicit six basic emotions were written up; seeking guidance from Reichenbach and Masters, (1983) and Stewart and Singh, (1995). All the vignettes were such that concealing ones emotions was not called for; all of the scenarios either had more than one person involved or the situation was such that expressing one's emotion would be the right thing to do. Because if children are aware of display rules they would not inhibit their ability to naturally express the emotion. Twelve adults were then recruited to label each vignette with the appropriate emotion, where six possible labels were provided. Only the vignettes which had 80% or above congruent rating (i.e. ones which were correctly labelled by 9 out of 12 adults) were retained for the experiment and the rest were rejected. Of these 12 with the highest ratings were selected to be finally included in the study (See Appendix 1).

  The stories were then given to 6 six primary school teachers teaching children with special needs i.e. various learning and educational difficulties. They were asked to state clearly if children aged 6 or above would find the stories simple and easy to comprehend and if not then to specify the difficult ones clearly. They were to also look at the language and words used in the stories for unfamiliarity and difficulty and specify those. All the teachers unanimously gave the feedback that each story was simple and that the language was accessible and familiar to children aged 6 with or without a learning difficulty (See Appendix 2).

Once the twelve stories were finalised I was filmed reading each story clearly, at normal reading speed for children, with as little intonation in voice as possible and minimal facial expression so as not to provide any additional clues to participants apart from the context of the story. This recording was copied to a DVD which could be played using media player. This was done so that vignettes can be presented in a standardised format to each participant and thus to minimise variation.

- Facial Action Coding System (FACS) - Ekman and Friesen (1978) produced FACS, which catalogued all possible distinguishable facial movements, termed facial action units (FAU), associated with each of the six basic FE of emotions. The FACS is a standard method for describing facial movements associated with each emotion (Ekman and Friesen, 1978) and I trained on FAU rating and facial muscles movement and achieved 94% reliability. Once having achieved the reliability, I practiced the facial movements needed for producing FE in order to produce the 10 facial movements necessary for the production of the six basic FE.

- Facial movement DVD: in order to check that all the muscles required for producing the six basic FE are functional and each participant is able to voluntarily control these facial muscles, the baseline task was designed. According to FACS, 10 FAU are necessary for producing the 6 basic FE. These facial movements as follows
    1. AU4: upper forehead (muscles contracting).
    2. AU2: eye brow (arch)
    3. AU5: eyes (wide opening)
    4. AU7: eyes (narrowing)
    5. AU 45: eyes blink
    6. AU9: nose wrinkle
    7. AU10: upper lip (open)
    8. AU17: lower lip (push upwards)

9. AU25/27: mouth open/ teeth clenched
10. AU20: lip stretcher

I was filmed performing each of the above facial movement at the normal speed after saying the label aloud, but once the facial movement was complete I held the exaggerated end facial muscle in position for 10 seconds. This recording was then made into a DVD which can be played with the sound using media player on any laptop computer.

- Coding sheet: Two data coding sheets were designed to score and record each of the facial movements and FE produced. It was thought that some expressions such as surprise may involve hand gestures and body part movement; bearing this in mind data coding sheet 1 was designed to record not only FEs but body movements. Since the experiment was primarily designed to investigate FE data, coding sheet 2 was designed where each correct FE was to be rated on a Likert scale of 1 to 7, 1 being very mild FE and 7 being intense FE. Also provisions were made to code any spontaneous FE. Any incorrect FE was not to be coded at all. The raters would be provided the information as to which FE was demanded and the task would be to code if participant produces the correct FE (See Appendix 2 and 3)
- A Sony camcorder was used to film each participant throughout the whole task. Each recording was then downloaded onto DVD to make 2 copies for future rating.
- A Laptop computer was used to play both the facial movement baseline task DVD and the short stories DVD to participants during testing.

10.2.2.3 Procedure

Each participant was tested in a quiet room on a one to one basis. Participants were explained the purpose of study in brief and informed that they will be filmed throughout the task. Active consent for filming as well as participation was sought from each participant.

Participants were then instructed that the first part of the task was to copy the faces I am making in the DVD and the second part of the task was to make the FE on their own without any copying. The first task started when the participant was ready and the experimenter had set the camcorder ready for filming.

10.2.2.3.1 Baseline task- when the participant was ready the instruction was to press play on the laptop computer which had the DVD for baseline task loaded and ready to be played. Once the play button was pressed on the computer the experimenter started filming using the camcorder.

The first instruction on the DVD was 'Please copy the faces I am making'. Then the 10 facial movement task started, first naming the face area that would be involved followed by actual facial muscle movement. For instance, first baseline task would be presented as "upper forehead" followed by visual presentation of forehead muscle contracting in order to display an exaggerated frown i.e. AU4 in action. When they had seen the facial movement being performed, participants would perform the task themselves. Once a FAU movement was presented on the DVD it was held in the exaggerated form for 10 secs in the video giving the participant plenty of opportunity to observe and copy. If the participant immediately achieved the task they would still have to wait for 10 secs while the facial movement on the DVD is displayed giving the participant opportunity for further scrutiny in order to improve their personal display, if they are not completely satisfied with their first attempt. I provided positive feedback if the task was achieved straight away or prompted participant to take a closer look and try again if they had not immediately achieved the task. Each participant was given the full 10 secs for each facial movement and if they did not achieve a particular facial movement at all then the DVD was paused, rewound and that facial movement shown again. This was done only once and then the participant was encouraged to move on and continue if they still did not achieve the facial movement. In total there were 10 facial movements and each participant needed to achieve at least 8 in order to move onto the FE production task.

10.2.2.3.2 Production of FE on demand

Once a participant has achieved the baseline task above the required threshold (i.e. 8 out of 10) then they would move to the next task. The computer was moved while I explained, "I am going to ask you to make some faces for me, please listen carefully and do what is asked of you. If you do not follow any instructions please ask to repeat immediately. Ok. When you are ready." Once participants indicated that they were ready for the task, I would ask them to produce the six basic FE one by one. These questions would be interspersed with other questions such as 'can you stick your tongue out for me?' To ensure that participants do not have problems following instructions and executing them (See appendix 4).

10.2.2.3.3 Story condition and production of FE with context

Once participants had finished the FE production task they would move to this task. If they have failed to produce any particular FE then before moving onto the context condition I verified whether they knew the meaning of that particular FE label, explained what was meant by that specific label and produced the FE to demonstrate what was expected.

For the context condition I started by saying, "Now I will present you with some short stories, you need to listen very carefully. I will then ask you how the person in the story is feeling. You need to choose one of these words to answer my question ok?" The six labels for the FE were shown in writing and the computer was again brought to fore and each participant was asked to indicate when they were ready to press the start button in order to play DVD 2 for the story. When the start button was pressed by the participant, I started filming. At the end of each story when it said – 'how would (character in the vignette) feel?' participants were expected to respond verbally and provide the FE label choosing one of the six labels provided. Handwritten labels for six FE were visible at all times for the participant. Once provided with the verbal label I would ask, 'Will you show me the face you make when you feel happy?' and participants would be expected to produce the relevant FE once again. After the first couple of times participants became accustomed to of the task and mostly produced FE after the labelling without any prompts.

At the end participants were thanked for taking part and working hard for the university.

10.2.3 Coding

Coding the video data – two raters coded each participants' facial movements and the FE produced for accuracy using coding sheet 1 and 2. I was trained on the FACS in order to identify the FAU units associated with each FE using the pictures and dynamic FE presented in FACS. The independent rater did not undergo the full FACS training but was familiarised with the FAU needed for the 6 FE, how to identify and rate them; how to notice the essential FAU and the non-occurrence of FAU. This was done using the FACS pictures and dynamic FE such that both the independent rater and I achieved 94 % agreement in the training session.

The independent rater and I coded the data independently and any discrepancy was first looked at by the independent rater individually and then reasons for the specific rating were discussed and we reached a consensus and common code.

Baseline tasks – were coded on a categorical scale of yes or no. A minimum of 8 was required in order to participate in the study which was based on FACS manual. All participants achieved 100 % accuracy on the baseline task. The inter-rater reliability was evaluated using Cohen's Kappa and the score was 0.86 which means a substantial agreement between raters.

FE on demand – FE produced on demand without any prompts, clues or context were then coded using coding sheet 2, part 1 independently by both the raters. This was on a Likert scale of 1 to 7. Only accurate FEs were coded for accuracy, clarity and intensity. FE on demand was ordinal data with more than two categories hence Cohen's Kappa could not be used here. The inter-rater reliability for this score was percentage of times the two raters agreed. Raters agreed on average 92% of times. This will be presented in detail later.

Instructional questions – were coded on a categorical scale of yes or no. All three questions received a coding of 'yes' for all the participants, meaning that participants achieved 100 % accuracy signifying they had no difficulty in understanding and executing the instructions. The inter-rater reliability was evaluated using Cohen's Kappa and the score was 0.96 which means a substantial agreement between raters.

Story labels – each FE had two vignettes and each vignette that was correctly labelled for emotion by the participant got a score of 1 and a wrong label got a score of 0. This meant that participants had the potential to get a score of 2 for each of the six basic emotions, making a possible total of 12. Since the basic score for each vignette could only be 0 or 1 once again Cohen' Kappa was used to examine the inter-rater reliability, which was above 0.8.

FE with context – once the stories were labelled FEs were produced which were considered by participants to be 'in context'. These FE were coded using coding sheet 2, part 2, once again independently by both the raters. Only the stories that were labelled accurately were scored for accuracy, clarity and intensity. This was on a Likert scale of 1 to 7. This will be presented in detail later. The inter-rater reliability was calculated as percentage of times the two raters agreed, which was 89 %.

Attempts were made to use the data coding sheet 1 when scoring FE on demand, story labels and FE with context. However, participants made very few significant hand and or body gestures linked with producing FE and hence this scoring was not included further in any analysis. This will also be discussed later.

The baseline score and instructional questions scores were not analysed any further. The rest of the scores were entered into an excel sheet and further analysed using SPSS version 12.

The inter-rater reliability was measured using Cohen's Kappa and the percentage of agreement among raters. This indicates the ratings assigned by both coders were very congruent. Both the independent- rater and I worked independently coding each and every participant without any knowledge of each others' ratings. The independent rater was completely blind to the purpose of the study. One of the reasons for such high level of agreement on coding FE is perhaps our training, based on FACS. FACS provides in great detail exactly which FAU the coders should inspect and what is needed to display a particular FE. Stewart and Singh (1995) report that their coders were trained on FACS and that study achieved a 94 % agreement between raters. Thus it can be concluded that FACS is a vital training tool for coding FE and even though researchers may not use specific FAU as a coding system; the training based on FACS provides a good grounding on exactly what to look for and code professionally.

10.2.4 Results

10.2.4.1 FE on demand

Mean accuracy data shows that 9-10-year-olds were marginally better than 6-7-year-olds in all the expressions except surprise. Both the groups produced accurate FE on demand without any prompts and clues and such FE were more intense and clear on the whole (See table10.1)

Table 10.1: Mean of accurate scores for FE production on demand based on Likert scale of 1 to7

	Happy	Sad	Angry	Fear	Surprise	Disgust
9-10 years	5.83	5.67	5.58	4.25	5.50	3.33
6-7 years	5.75	5.00	5.58	3.67	5.92	2.92

A 2 (age groups: 10 and 6) X 6 (FE: happy, sad, angry, fear, surprise and disgust) split plot ANOVA was conducted. The effect of facial expression was significant ($F = 17.53$, $p = 0.001$), the main effect of age was not significant ($F = 0.38$, $p = 0.54$), meaning performance of both age groups was same. The interaction was not significant ($F = 0.23$, $p = 0.88$).

Both 6-7-year-olds and 9-10-year-olds behave in a similar manner for FE production on demand. The age effect was not significant indicating that both age groups behaved same, hence all the data was collapsed to one group and paired sample t-tests were carried out to examine the main effect of FE condition . Happy, sad, angry and surprise were significantly different to fear and disgust (See Table 10.2. for all significant t-test and p values).

Table 10.2: t-test and p values for FEs that were significantly different to fear and disgust FE

	t-test	p	
Happy	4.11	0.001	For fear

	4.35	0.001	For disgust
Sad	2.65	0.01	For fear
	3.42	0.002	For disgust
Angry	2.91	0.008	For fear
	3.56	0.002	For disgust
Surprise	3.13	0.005	For fear
	4.05	0.001	For disgust

There was no significant age difference in the production of FE taking clarity and intensity of FEs into consideration. Angry FE was produced with the same clarity and intensity on average by the two age groups tested here. FEs happy, sad and fear FEs produced by 9-10-year-olds were better that FEs produced by 6-7-year-olds but the difference failed to reach levels of significance. Happy, sad, angry and surprise were significantly better than fear and disgust FEs produced by both groups. Disgust FE got very poor score, with 6-7-year-olds performing particularly poorly.

10.2.4.2 Story labels

Participants were asked to label the emotions of the characters in the stories. The mean accuracy scores for correct labels provided shows that on average 9-10-year-olds performed better (See Table 10.3) than 6-7-year-olds.

Table 10.3: Mean scores for accurate story labels based on scale of 0 to2

	Happy	Sad	Angry	Fear	Surprise	Disgust
9-10 years	1.42	2	0.83	1.92	1.42	1.17
6-7 years	1.58	1.83	0.25	1.08	0.83	1.33

A 6 (FE) X 2 (age) split plot ANOVA was conducted. The main effect of FE ($F = 4.92$, $p = 0.03$) was significant and the main effect of age ($F = 9.02$, $p = 0.007$) was also significant. The interaction was not significant ($F = 0.39$, $p = 0.53$).

The main effect of age was further analysed using independent sample t-test. Fear ($t = 4.89$, $p = 0.001$) and angry ($t = 2.75$, $p = 0.012$) were labelled significantly better by 9-10-year-olds compared to 6-7-year-olds.

The main effect of FE was further analysed using paired sample t-test. 9-10-year-olds mean accuracy for FE labelling of sad and fear were significantly different to happy, angry, surprise and disgust (See table 10.4), with performance for anger being the worst and sad being the best.

Table 10.4: t-test and p values for the story labels that are significantly different for 10-year-olds

	t-test	p	
Happy	3.92	0.002	For sad
	3.02	0.012	For angry
	3.31	0.01	For fear
Surprise	3.02	0.01	For sad
	2.56	0.02	For fear
Disgust	3.45	0.005	For sad
	2.69	0.02	For fear
Anger	5.61	0.001	For fear
	7	0.001	For sad

Table 10.5: t-test and p values for the story labels that are significantly different for 6-7-year-olds

	t test	p	
Happy	7.09	0.001	For angry
	2.17	0.05	For fear
	2.46	0.03	For surprise
Sad	10.65	0.001	For angry
	3.44	0.005	For fear
	4.06	0.002	For surprise
	2.17	0.05	For disgust
Angry	3.45	0.005	For fear
	2.54	0.02	For surprise
	4.73	0.001	For disgust

The mean scores demonstrate that the ability to label FEs of 6-7-year-olds are similar to 9-10-year-olds, for both the groups the judgements of sad emotion is the best and of angry emotion is the worst. 6-7-year-olds ability to label the happy emotion is significantly better than their ability to label angry, fear and surprise. Their ability to label sad is significantly better than everything except happy and labelling anger is significantly worse compared to everything else (See Table 10.5).

Emotion labels for the characters in the stories were provided more accurately by 9-10–year-olds compared to 6-7year-olds. Older children were significantly better than younger children in labelling fear and anger. Within group analysis revealed that 9-10-year-olds labelling of sad and fear was best and significantly different to their own performance for happy, anger, surprise and disgust. 9-10-year-olds labelled sad most accurately, scoring the perfect score of 2 on average and labelled anger the least accurately, scoring on average only 0.8. Within group analysis of 6-7-year-olds revealed that labelling of the anger emotion was least accurate and it was significantly different to all the other emotions labelled. They also found labelling the surprise emotion very difficult; performance was poor and significantly different to performance for all other emotions except fear. Like older children, performance for sad was the most accurate and this was significantly better than anger, surprise, fear and disgust.

10.2.4.3 FE production with context

Children were provided the context of each emotion through short stories and were then asked to produce FE. The performance of 9-10-year-olds was better than 6-7–year-olds. In order to examine this difference more closely a 6X2 split plot ANOVA was conducted which showed that main effect of age was significant ($F = 4.27$, $p = 0.05$). The main effect of FE ($F = 4.32$, $p = 0.05$) was also significant but interaction was not significant ($F = 0.22$, $p = 0.64$).

The main effect of age was further analysed using an independent sample t-test which showed that older children were significantly better than the younger group in the production of happy FE ($t = 1.99$, $p = 0.05$) and angry FE ($t = 2.28$, $p = 0.03$).

Table 10.6: Mean of accurate scores for FE production within context based on Likert scale of 1 to7

	Happy	Sad	Angry	Fear	Surprise	Disgust
9-10 years	6.17	5.5	4.08	4.75	5.08	4.25
6-7 years	5.42	4.83	1.67	3.92	4.17	4.08

The main effect of FE was further analysed using paired sample t-test with split file data; this showed that within group happy was significantly better for 9-10-year-olds but the other expressions were not significantly different to each other in production. For 6-7-year-olds production of angry was significantly worse than the rest of the FE and happy was significantly better. There were no other significant differences.

10.2.4.4 Comparison of FE with and without context

Paired sample t-test was carried out to investigate if FEs produced on demand were significantly different to those produced within context. Production of FEs with and without context was not significantly different for 9-10-year-olds. Context did not make an impact on FE production in a way that production improved or deteriorated significantly when explicit context was provided. Production of FE with and without context was significantly different for 6-7-year-olds in the case of angry FE ($t = 4.1$, $p = 0.002$), surprise FE ($t = 2.29$, $p = 0.04$) and disgust FE ($t = 3.88$, $p = 0.003$). Examining the mean score for FEs produced with and without context we can see that with context performance for disgust improved but performance of anger and surprise was significantly worse.

10.2.5 Discussion

10.2.5.1 Baseline task

This was designed to evaluate if all the muscles required for producing six basic FE are functional and under voluntary control of the participants. In all a score of 8 out of 10 was required to participate further in the study. This was based on FACS because all FAU may not be used to express a specific FE. For example, disgust FE can be achieved either by protruding ones tongue out or wrinkling nose or a combination of both. Now if a participant in baseline task failed to achieve nose wrinkle (AU9) then there is no guarantee that they will not be able to produce disgust FE. They may still be able to display disgust FE by protruding tongue. Similarly, angry FE may be achieved by narrowing the eyes (AU7) or forehead contracting (AU4) or a combination of both. These were highlighted very well by FACS which I took on board when designing the requirements and set the minimum to 8. However, this sample of typically developing 6-10-year-olds achieved 100 % in baseline task, demonstrating that facial muscles required for producing six basic FE were completely functional and under their voluntary control. All participants went ahead with rest of the tasks of the study. This task was successful in evaluating the muscular movement and voluntary control and the FACS system has been the main tool enabling such a design to be developed.

10.2.5.2 Instructional questions

These were set in order to evaluate if participants have any difficulty in understanding and executing instructions. Three instructional questions were asked and all the participants achieved 100 % in terms of accuracy. This signified that all participants had the ability to comprehend instructions and carry them out. Through this it can be ensured that failure to produce FE is not failure to understand instructions or difficulty in carrying them out. Instructional questions have been an easy but effective way of investigating if participants can comprehend simple instructions and carry them out. Herba and Phillips, (2004) state that it has been difficult to investigate FE production to certain extent due to the confounding factor of verbal ability. Although, verbal ability as a confounding factor for story condition cannot be completely eliminated, these instructional questions enabled to minimise the effect of verbal ability at least in the FE production condition. Since the experiment was developed to investigate children with autism's FE production ability, it is essential to ensure that there is no problem in participant's understanding and following instructions to produce FE, what can only be classed a 'social instruction'. The findings with MC demonstrate that the task is effective and hence will be useful in autism research.

Children made very few gestures and these were not linked with FE production, as a result the data coding sheet 2 did not generate enough data for further analysis. It was decided not to continue coding data using coding sheet 2 but to code FE data only using coding sheet 1.

Spontaneous FEs were also not produced often enough in order to generate sufficient data for further analysis and hence it was decided not to continue to code for spontaneous FE either.

10.2.5.3 FE produced on demand

Moving onto matters more pertinent, production of FE, I first consider FE produced on demand, without any prompts, clues or context. Participants were asked to produce a particular FE in a voice which was very monotonous (so as not to provide them any clues) and any feedback in this part was avoided.

Production of happy FE was best for both age groups closely followed by surprise. FE recognition literature states that recognition of happy is first acquired at the age of nearly 4 months of age (Nelson, 1987). This is followed by sad and angry, followed by surprise (Gross and Ballif, 1991; Herba and Phillips, 2004) with fear and disgust emerging much later (Widen and Russell, 2003). From the mean scores for clarity and intensity of 9-10-year-olds it appears that for FE production there is a similar pathway for FE production. Average scores for happy were best, followed by sad, anger, then surprise, then fear and finally disgust being produced with minimum clarity and intensity. In the case of 6-7-year-olds the trend is slightly different and although all average scores are close to each other, production of surprise was surprisingly best followed by happy, anger, sad and fear. Production of disgust by 6-7-year-olds was worst and this was a combination of failing to produce the disgust expression completely and producing expressions that were not very clear which failed to receive high scores on Likert scale for clarity and intensity and not having the understanding of the word disgust. This is in line with recognition literature which states that young children fail to recognise disgust (Kolb et al., 1992) or start to label disgust at age of 5 (Widen and Russell, 2003) or seven (Harris et al., 1987). It is possible that a child as young as 6-7 years of age does not consistently understand disgust and cannot produce it accurately.

By the age of 10 years children can categorise happy and sad at a level comparable to adults (Gosselin, 1995). The literature reports, however mixed findings for anger and surprise with Gosselin, (1995) reporting happy and anger to be of same difficulty while Camras and Allison, (1985) reporting that anger is harder than happy but easier than disgust. The results presented here reflect that for production both anger and surprise FEs were on par with happy for both age groups. Only fear and disgust were significantly worse than other FEs produced.

Production of disgust follows the recognition of FE trend, recognition of disgust is not reliably established until the age of 14 (Kolb et al., 1992) in the study reported here 9-10-year-olds failed to produce disgust FE very well.

Children of both age groups have found production of fear FE difficult and this is in conflict with the recognition literature for fear FE which claims that recognition of this expression to be on par with surprise (Gross and Ballif, 1991). Literature on FEs emphasises that the functions of FEs are as tools for communication (Blair, 2003) or to express the emotion person is experiencing (Ekman, 1997). From either of these premises it is clear that individuals cannot produce FEs without actually feeling the emotion. This function of FE is not to be confused with the display rules. According to display rules individuals may be able to express the emotions they may not feel or display different emotion to the ones they feel. The primary assumption is it is harder to produce complex emotions without experiencing the emotion but with practice easier to disguise when experiencing the emotion. At the same time it is easier to display simple emotions such as happy without experiencing the emotion too intensely. So, when I say in the study that FE was produced without any context it means no explicit context was provided to the participants either by voice intonations, or prompts or actual emotion inducing stories. This means participants must be self inducing the emotion in order to produce a FE and the scores of happy and surprise indicate that these are rather straight forward emotions to induce and produce FEs for on demand.

Children of both age groups presumably found it difficult to self-induce the emotions of fear. This was evidenced by the intensity of the fear FE being quite low in comparison to other FEs.

10.2.5.4 Story labels

All participants made some mistakes so the total score of 12 was not achieved by any participant. Both groups were best at labelling the sad emotion for the character in the story. 9-10-year-olds performance for fear emotion was next best which is in line with previous research (Widen and Russell, 2003). Accurate labelling of happy and surprise was on par for 9-10-year-olds and just like Reichenbach and Masters, (1983), in this experiment the older children misjudged happy more than 6-7-year-olds. The other similarity with the literature is how the anger emotion was more often misjudged as sad (Reichenbach and Masters, 1983); in the experiment reported here children generally labelled both sad and angry story conditions as 'sad', resulting in very low scores for the angry FE.

Both groups were poor in labelling the angry emotion, 6-7-year-olds being poor particularly worst at identifying the emotion of the character in the story as angry and the maximum score on average was 0.25 out of 2. There are 2 angry scenarios, out of these only 3 participants from the 6-7-year-olds group were able to label one of these scenarios accurately. All the participants in the younger age group got the other story on angry wrong. The story that 6-7-year-olds struggled with most was (story 2 – Appendix 1) where a toy is broken and the child is expected to be angry with his friend. However, younger children labelled the emotion here as sad. Anger in general was misjudged as sad by both groups. Sad is an internal emotion affecting only the self (Blair, 2003), whereas angry is a relational emotion. This highlights that this group of younger children were more comfortable in the emotion affecting self than expressing or feeling relational emotion. Reichenbach and Master, (1983) also reported that anger from context was often misjudged to be sad and one of the reasons given by the authors was the existence of as disparity in the conceptualisation of emotion in terms of perceptual cues and context. The other reason given by Reichenbach and Masters, (1983) was the fact that *display rules* and cultural values have an impact. States such as anger are more likely to be disguised and part of socialisation may be learning not to display anger or to disguise it as other emotions such as sadness. The consequence of such training would be (a) to misread when anger is displayed behaviourally as something else and (b) an assumption that many contexts that should induce states of anger will actually fail to do so because the assumption is the person has 'risen above' it. The FEs that seems to undergo this socialisation effect the most are the negative ones such as anger, fear, disgust and sad (Reichenbach and Masters, 1983). In my stories sad does not seem to have such an effect and children in general seem capable of identifying sad correctly from the context. Performance for anger seems to suffer however. This should be a good indication of how indoctrinated social beings are and how typically developing individuals learn these social rules and apply them automatically.

One option was to change the angry stories so as to make the angry emotion more obvious in the vignettes, this had three implications. One, the obvious ethical constraints particularly because I was drawing participants from a vulnerable population. Second, I was wary of making the stories so outlandish so that they do not remotely represent real life and thus children saw them more as fairy tales and were unable to relate to them on a personal level. Finally, the main aim of the study was to investigate FE production in children with autism particularly those with HFA who are in mainstream education. Autism, as mentioned several times before, is a social disorder with deficits in communication, interaction and imitation. HFA children may not have the knowledge, experience or practice of such elaborate *display rules* and socialisation and may not be affected in the same way as with children. And if they do demonstrate the same pattern of accuracy it will mean that HFA children are as knowledgeable as MC in display rules and socialisation.

On the whole, it was decided that since the aim of context is to facilitate FE production it would be best to leave the actual vignettes as they were but to change the instructions slightly. It was important that participants knew they could only choose one emotion label for the character.

The performance of 9-10-year-olds labelling of disgust confirms the impact of *display rules* and socialisation values yet again. The stories eliciting disgust emotions are very direct and children as young as six were able to correctly identify it 66 % of the time. Perhaps 9-10-year-olds have learnt to restrain explicit expression of disgust or disguise it with other emotion such as surprise. As a result more misjudgements for disgust were made by 9-10-year-olds than by 6-7-year-olds.

Anecdotal verbal evidence during feedback after the completion of the test enlightened me to the fact that children's understanding of some FE labels may be different to what was expected of them. When asked what did they understand by 'disgust' numerous participants, especially the younger children, gave scenarios which actually described anger, particularly anger directed towards them by an adult. This resulted in a change in procedure to request that participants read FE labels aloud allowing me to check with them if they understood each label. This was particularly useful for fear and disgust after the FE on demand task was completed and before embarking on context condition.

10.2.5.5 FE production with context

Once the emotion of the character in the story was correctly identified, this was considered as the context being correctly identified. The aim was to investigate if this impacted on FE production in children 6-10 years of age, especially in terms of clarity and intensity. The FE produced with context is very interesting and prompts re-evaluations of both on FE production in general as well as the impact of context. When FE was produced on demand FEs such as happy, sad, angry and surprise were of good quality (taking clarity, intensity and accuracy into consideration). It was assumed that participants self induced emotions to produce these FE on demand either using FE as a tool to communicate the emotion demanded or to show the emotion by experiencing it first. In either case since further prompts and clues were not provided production is assumed to be by self induction and there was no age difference.

When context was provided the results indicate a significant age difference. This could be interpreted to suggest that all FE production improved with context but on the contrary children behaved differently for different FEs with context.

The 9-10-year-olds were significantly better than the 6-7-year-olds in their production of angry FE with context. When there was no context the performance (clarity, intensity) of both age groups was exactly the same for anger; provision of context instead of facilitating production had a negative impact on the performance of 6-7-year-olds. The data for 6-7-year-olds labelling and production of angry FE within context shows that inaccurate labelling not only led to inaccurate production (resulting in zero score for production of anger FE) but also reduced the intensity with which such FEs were produced even when the labelling was accurate. The performance with context was significantly worse than the no explicit context condition. With self induction children could produce FEs, which scored high for intensity and clarity, but when context was provided (a) anger got misjudged to sad (perhaps due to *display rules* Reichenbach and Masters, 1983) and (b) a reduction was seen in the intensity and clarity of FE. Reichenbach and Masters, (1983) stated that the most likely emotions that undergo such socialisation effects seem to be negative ones such as anger. In the present study this was certainly the case. *Display rules* along with social and cultural values induced by specific context, impacted on the labelling of the anger emotion and the respective FE production. FEs produced on demand demonstrated that children as young as 6 can produce anger FE and this is in accordance with the labelling literature (Widen and Russell, 2003) and recognition literature (Gosselin, 1995; Gross and Ballif, 1991), all claiming that children at that age can recognise and discriminate anger FEs. In the data reported here for anger FE produced it is clear that overarching 'display rules' nullify the two functions of FE (namely as tools to communicate and express emotions experienced).

The performance for happy FE improved for 9-10-year-olds with scores reaching nearly ceiling limits (6.17 out of 7). This was in spite of the fact that older children made more misjudgements in labelling happy than 6-7–year-olds. Nonetheless, when happy was judged accurately by older children in the story condition it was produced with greater intensity and clarity. The improvements or the decrements were not significant which means context did not make significant impact on happy for either age group.

Production of fear and disgust improved with context, with 6-7-year-olds showing the most remarkable improvement in their production of disgust. These two FEs suffered the most without any context and the data showed that children struggled to self induce these two emotions in order to produce the appropriate FE with adequate clarity and intensity. The story condition definitely facilitated the production of these two FEs because when asked to produce FEs on demand, production of fear and disgust was significantly worst than the rest of FE produced and this was for both the age groups. However, when context was available performance for fear and disgust improved and these FEs were no longer significantly different to rest of FEs produced in context. Analysis also revealed that for 6-7-year-olds disgust FE produced with context was significantly better than disgust FE produced on demand. This is in accordance with recognition literature which claimed disgust FE to be the most difficult to recognise (Kolb et al., 1992) and that an increase in intensity facilitated recognition (Herba et al., 2007). In other words, additional information facilitated the recognition of disgust and additional information in the form of context facilitated the production of disgust, especially for 6-7-year-olds.

The sad emotion was recognised most accurately in the stories presented, with the 9-10-year-olds achieving perfect scores of 2 on average in the labelling task. However, labelling did not facilitate production of sad FE immensely and sad FE produced with context remains on par without context.

The fear emotion, like sad, was labelled effectively but labelling did not facilitate production and production with context was similar to production without context with no significant difference for both groups.

Surprise FE deteriorates with context again highlighting that positive FEs are easier to self induce, and showing a negative impact of context on production. In 6-7-year-olds production of the surprise FE with context was significantly worse than production on demand. For older children production of surprise FE with context also suffered marginal decrement but this difference was not significant.

On the whole it can be concluded that FE production follows a similar path to recognition: happy is the easiest to produce, both with and without context, and disgust is the hardest, especially without any context. it has also been demonstrated that, context may not make a huge difference to producing FEs that are easy to produce, such as happy and sad, but that it definitely facilitates those FEs that are hard to self induce, such as fear and disgust. The story labelling task may be influenced to a certain extent by display rules and social values because these values are indoctrinated in individuals from a very early age. Anger shows the greatest influence of *display rules* and social perceptions and it is easier to produce anger with better clarity and intensity without any context than when a specific context is given.

Finally, it can be concluded that tasks developed to measure FE production work well. These tasks are able to demonstrate that despite all the confounding factors emphasised in the literature for investigating FE production (such as verbal ability, scoring, prosody, and context) it is possible to investigate production of FE. The method of scoring FE produced also has been demonstrated here to be more effective than simple dichotomous yes or no data, and successful in not only measuring if FEs are produced but also how clear and intense these are, which was made possible partly by FACS.

10.3 Aim of experiment 2: Investigation of FE production in HFA sample and matched controls (MC)

In Experiment 1 I demonstrated that MC children aged 6-7 years and 9-10 years were able to successfully produce FE both on demand and in context. The data demonstrates that context facilitates production of emotions that are hard to self induce such as fear and disgust whereas FE like happy and sad can be produced without any context quite easily by self induction of emotion. When children are asked to label the emotion of the character in the story and think in terms of FEs, display rules and social values have been shown to influence performance.

Having confirmed the above the study progressed to investigate the ability of the HFA sample and examine any group difference with a sample individually matched for IQ and chronological age (CA) in the following

1. To investigate the ability to produce FE on demand.
2. To investigate if context has any impact on production of FE.
3. To investigate the ability to label emotions of the characters in emotion vignettes.

10.3.1 Hypotheses

1. My first prediction was that HFA children would be able to produce simple FEs such as happy and sad but would struggle with complex FEs such as disgust.

2. My second prediction was that there would be no significant difference between the HFA sample and the MC in production of simple FEs such as happy and sad

but there will be a significant difference for complex FEs such as disgust. The general assumption in research is that individuals with autism have a deficit in FE recognition. It has been reported that toddlers can copy FE with explicit instructions but not implicitly. However, in Chapter 9 under investigation of inner-outer FR, I have reported that a HFA sample was able to execute holistic face processing at a level similar to MC. It is in light of this finding, as well as those reported by Wilson et al., (in press) and Spezio et al., (2007), that the first prediction is made.

3. My final prediction was that there will be no significant group difference in the labelling of the six basic emotions. Literature highlights that individuals with autism are better at labelling emotions than recognising FEs, especially high-functioning individuals (Oznoff et al., 1990).

Exploratory investigation was carried out to examine FE production within context and as such a prediction could not be made for this part of the investigation.

10.3.2 Method

10.3.2.1 Participant

See chapter 6 for a detailed account of recruitment, inclusion and exclusion criteria and matching groups.

HFA and matched control sample

Twenty-one HFA children aged 9 to 15 matched individually for both CA and IQ to twenty-one MC children were tested (see table 10.7). Actual age and IQ of each participant is in appendix 5.

Table 10.7: Mean age and IQ for HFA and MC

	Mean Age	Mean FSIQ	Mean VIQ	Mean PIQ
Matched controls (MC)	12.98	106.11	104.94	106.11
HFA sample	13.11	105.94	106.11	104.64

10.3.2.2 Apparatus and material

This was exactly same as in experiment 1 of FE production reported in this chapter.

The ADI-R was used to administer semi-structured interviews to 7 out of 22 parents in order to confirm the autism diagnosis.

The WASI was used to measure verbal and non-verbal IQ to produce a full scale IQ for all participants in order to match each participant from HFA sample to MC.

The CARS was administered as a questionnaire to screen participants for autism.

10.3.2.3 Procedure

This was exactly same as for the FE production experiment reported in this chapter.

The CARS was administered first for screening participants for autism. The baseline task was administered first, followed by FE on demand, then labelling the emotion of the character in the story condition and finally asking participants to produce the FE that will best indicate the label provided.

The WASI was administered first to HFA and then to groups of MC and individuals who matched for CA and IQ were then tested for the FE study.

10.3.2.4 Results

Baseline tasks were coded on a categorical scale of yes or no. A minimum of 8 was required in order to participate in the study which was based on FACS manual. Most of the HFA participants scored 100 %, but a few had a score of 9. Anecdotal verbal feedback suggested that they struggled with AU4 (upper forehead muscles). However, since on average at least 9 was achieved by everyone this was not analysed any further. The inter-rater reliability was evaluated using Cohen's Kappa and the score was 0.81 which means a substantial agreement between raters.

Instructional questions data were coded on a categorical yes no scale which demonstrated that all participants understood the instructions and followed them.

Inter-rater reliability was evaluated using Cohen's Kappa and the score of above 0.8 showed significant agreement between the raters. This was not further analysed.

10.3.2.4.1 FE on demand

FE produced on demand without any prompts, clues or contexts were then coded using coding sheet 2, part 1 independently by both the raters on a Likert scale of 1 to 7 with 1 for mild and low intensity and 7 for high clarity and intensity FE.

The mean score for accurate FE produced on demand show that the MC were better than HFA sample for intensity and clarity (see table 10.8)

Table 10.8: Mean score for FEs produced on demand by HFA and MC, on the Likert scale of 1 to 7, 1 = mild and 7 = intense

Group	Happy		Sad		Angry		Fear		Surprise		Disgust	
	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd
HFA	5.32	1.46	4.09	1.99	4.05	2.29	3.59	2.5	4.36	2.06	1.55	4.96
MC	6.18	0.73	5.55	0.73	5.77	1.41	4.27	2.33	5.95	0.99	4.23	2.77

A 2 (HFA and MC) X 6 (FE: happy, sad, angry, fear, surprise and disgust) split plot ANOVA was conducted. The main effect of FE was significant ($F = 24.89$, $p = 0.001$), demonstrating that happy and surprise were produced with higher clarity and intensity than fear and disgust to low intensity and clarity. The main effect of group was also highly significant ($F = 11.6$, $p = 0.001$) demonstrating that overall performance of HFA group was significantly worse than MC. The interaction was not significant ($F = 0.98$, $p = 0.32$). The HFA sample was in general worse than MC with disgust FE showing the greatest difference between groups.

The main effect of group was further analysed using independent sample t-test to examine the difference. Except for fear, all other FE produced by the HFA sample were significantly worse than MC (see table 10.9). The means show that HFA were as good as MC in the production of fear FE on demand but for the rest of the FE they were significantly worse than MC.

Table 10.9: t-test and p values for significantly different FE between HFA and MC

t-test	p values	Significant difference between both groups for
2.48	0.17	Happy FE
3.20	0.003	Sad FE
3.003	0.004	Angry FE
3.26	0.002	Surprise FE
2.21	0.03	Disgust FE

The main effect of FE on demand was further analysed using paired sample t-test on split data. The results show that for MC production of fear and disgust was significantly worse to rest of the FE produced by them (see table 9.10). Other FEs produced, such as happy, sad, angry, and surprise, were not significantly different to each other within sample for MC. The results show that for HFA sample production of happy was significantly different to all FEs except surprise within sample; while disgust was significantly different to all other FEs produced within sample. The happy FE showed best production taking clarity and intensity into consideration (see table 9.11) and disgust was the worse taking clarity and intensity into consideration. Other FE produced by the HFA sample, such as sad, angry, fear and surprise, were not significantly different to each other within sample for HFA sample.

Table 10.10: t-test and p values for significantly different FEs produced by MC (within sample)

	t test	p values	Significant difference
Happy	4.28	0.001	With fear
	3.51	0.002	With disgust
Sad	3.05	0.006	With fear
	2.44	0.02	With disgust
Angry	3.33	0.003	With fear
	2.89	0.009	With disgust
Surprise	3.31	0.003	With fear
	3.22	0.004	With disgust

Table 10.11: t-test and p values for significantly different FEs produced by HFA (within sample)

	t-test	p values	Significant difference
Happy	3.15	0.005	with sad
	2.55	0.018	with angry
	3.38	0.003	with fear
	3.48	0.002	with disgust
Sad	2.44	0.02	with disgust
Angry	3.02	0.006	with disgust
Fear	2.93	0.008	with disgust
Surprise	2.09	0.49	with disgust

The HFA sample was significantly worse in comparison to the MC when asked to produce FE on demand without any prompts or clues. All FEs except fear FE produced by the HFA sample was less expressive than MC taking clarity and intensity into consideration.

When the FE within group is compared the HFA sample produced positive FE, i.e. happy and surprise, with greater clarity and intensity. Happy was otherwise significantly different to all the other FE produced by them. The data highlights that the HFA sample struggled the most in producing disgust FEs, scoring very low for clarity and intensity. This is also the case for fear FE. When FE within group is compared for MC their FE production for happy, sad, angry and surprise are similar for clarity and intensity and all these FEs are significantly different to fear and disgust. The mean score for fear and disgust was about 4.5 on a Likert scale of 1 to 7, which suggests that fear and disgust FEs produced on demand are or low clarity and intensity in comparison to other FEs.

10.3.2.4.2 Story labels for emotion

The mean scores for accurate labelling of the emotion for the character in the story condition show that the MC were similar to the HFA sample for all FEs in this condition (See table 10.12)

Table 10.12: Mean of scores for story labels by HFA and MC based on a scale of 0 to 2

Group	Happy		Sad		Angry		Surprise		Fear		Disgust	
	Mean	sd	Mean	sd	Mean	Sd	Mean	sd	Mean	sd	Mean	sd
HFA	1.36	0.49	1.77	0.52	1.18	1.18	1.64	0.58	1.64	0.58	1.36	0.79
MC	1.55	0.51	1.86	0.35	1.27	1.27	1.73	0.45	1.91	0.29	1.73	0.55

A 2X6 split plot ANOVA was conducted to examine group difference. The main effect of group was marginally significant (F = 4.29, p = 0.04) but the main effect of FE was not significant (F = 1.17, p = 0.28) and the interaction was not significant (F = 1.03, p = 0.31). This means performance for labelling of the six emotions within group is very similar and although the difference between HFA and MC is significant this significance is very marginal. The main effect of group was further analysed using independent sample t-test which showed that despite differences between means performance for fear was not significantly different between group (t = 1.96, p = 0.056). The performance for disgust is also not significantly different (t = 1.77, p = 0.08).

This meant that the HFA sample even though they were significantly worse than the MC in production of FE on demand, the labelling of characters' emotion did not show this difference to the same level of significance between groups. The mean accuracy scores show that MC were extremely good at labelling fear, with the scores reaching nearly ceiling limits. In comparison performance of HFA were poor for the fear emotion in the story.

10.3.2.4.3 FE produced with context

Participants were provided context for each FE, asked to label the emotion in the story and then produce the FE. The mean of scores for accurate FEs produced with context shows that FEs produced by the HFA sample was inferior to those of the MC for clarity and intensity.

A 2X6 split plot ANOVA was conducted to analyse the difference. The main effect of group was significant (F = 24.75, p = 0.001), which shows that the HFA were significantly worse than the MC in producing FE when context was available. The main effect of FE was also significant (F = 13.48, p = 0.001), showing that some FEs were easier to produce, such as happy, whereas others were significantly difficult to produce, such as disgust and fear. The interaction was not significant (F = 1.16, p = 0.28).

Table 10.13: Mean of scores for FEs produced with context by HFA and MC on the Likert scale of 1 to 7, 1 = mild and 7 = intense

Group	Happy		Sad		Angry		Fear		Surprise		Disgust	
	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd
HFA	5.59	1.61	3.64	1.94	3.32	2.64	3.55	2.36	4.68	1.98	3.45	1.56
MC	6.5	0.51	5.59	1.18	5.27	1.93	5.32	1.12	5.86	0.71	5.5	2.52

The main effect of group was further analysed using independent sample t-test. The t-test scores clearly indicate that the performance of the HFA sample for all FEs were significantly worse than the MC (see table 10.14).

Table 10.14: t-test and p values for significantly inferior FEs produced with context by HFA compared to MC

t-test	p values	Significant difference between both groups for
2.51	0.01	Happy FE
4.-04	0.001	Sad FE
2.8	0.008	Angry FE
3.17	0.003	Fear FE
2.63	0.01	Surprise FE
3.23	0.002	Disgust FE

The main effect of FE was further analysed using paired sample t-test on split data. For the MC the t-test and p value show that the happy FE was significantly different to all other FEs, reaching ceiling limits for clarity and intensity when context was provided. The rest of the FEs were not significantly different to each other within sample for MC (see table 10.15)

Table 10.15: t test and p values for significantly different FE produced by MC within sample

t test	p values	Significant difference between FEs
4.004	0.001	Happy and sad FE
2.98	0.007	Happy and angry FE
5.13	0.001	Happy and surprise FE
5.26	0.001	Happy and fear FE
2.93	0.008	Happy and disgust FE

The t-test and p value for the HFA sample when context was available shows that production of happy FE was significantly different to all other FEs except surprise and that surprise was significantly different to sad, angry and disgust FE. The mean scores indicate that production of Happy FE reached the maximum for clarity and intensity closely followed by surprise (see table 10.16).

Table 10.16: t-test and p values for significantly different FE produced with context by HFA within sample

t-test	p values	Significant difference between FEs
3.82	0.001	Happy and sad
3.61	0.002	Happy and angry
3.42	0.003	Happy and fear
4.08	0.001	Happy and disgust
2.76	0.01	Sad and surprise
2.83	0.01	Angry and surprise
2.12	0.04	Surprise and disgust

10.3.2.4.4 Comparison of FE with and without context

The HFA sample's production of FEs on demand when compared to FEs produced in context shows no significant difference, meaning FE production did not improve or deteriorate with context.

This same comparison for the MC that happy (t = 2.3, p = 0.03) and fear (t = 2.1, p = 0.04) FE were significantly better when context was provided. When context was provided the mean for disgust FE increased by a similar amount as for happy FE and fear FE. This difference did not reach significance however, possibly due to the large standard deviation of this data set (See table 10.17)

Table 10.17: The standard deviations in the three sets of data for MC

Expressions	sd
Happy	0.64
Fear	2.2
Disgust	3.19

10.3.2.4.5 Correlation between IQ and production scores

Following the rationale discussed in section 9.3.3.5 it was decided to investigate the correlation between FE production scores and IQ. The only correlation that was marginally significant (p = 0.045) was between story label scores of fear and IQ for HFA (See appendix 6). This is a positive correlation i.e. as the IQ scores increased the accuracy for story labels increased. Since this is very marginally significant it will not be explored further.

10.4 Discussion

The baseline tasks were designed to check if participants can use the facial muscles necessary for FE production and if this is under the voluntary control of participants. All participants from both groups clearly demonstrated that they can use the facial muscles and that these muscles are completely under their voluntary control. An instruction questions task was designed to examine whether participants can understand instructions and carry them out. All participants successfully carried out all the instructions they were given thus proving that they were capable enough to understand the instructions and carry them out. From these two tasks it can be concluded that if the HFA sample is different to the MC it was not because their facial muscles were not functional, they could not control them or that they cannot understand and carry out instructions.

10.4.1 FE on demand

One of the main focuses of the thesis was to explore if HFA children can produce FEs. Literature highlights that the autism population have a deficit in FE recognition and discrimination and that this persists into adulthood at which stage even if accuracy is achieved at similar levels to MC the strategy used is atypical (Joseph and Tanaka, 2003; Klin et al., 1999) or there is a speed accuracy trade-off (Behrmann et al., 2006).

To my knowledge, failure to adequately use FE, which is one of the cardinal features of autism according to the ICD-10 (WHO, 1994) and the DSM-IV (APA, 1994), has not been investigated from the perspective of FE production to date, especially in adolescents with HFA. The studies that have investigated to a limited extent FE production in population with autism have exclusively focused on toddlers, and examined their ability to imitate FEs either implicitly or explicitly (McIntosh et al., 2004; Rogers et al., 2003.).

The present study firstly investigated the ability of a HFA sample to produce FE on demand without any prompts, clues or explicit context. It compared this data with a sample matched on a one-to-one basis for CA and IQ. The HFA sample, when asked to produce FE on demand, was able to produce all the FEs albeit at a level significantly worse than MC. The first prediction was that HFA sample will be able to produce FEs such as happy and sad. Production of FE by autism population has not been investigatged to my knowledge hence it was not possible to predict the level of performance. The fact that HFA sample produced expression which scored above zero on average it can be assumed that first prediction was met. The performance was in fact, beyond the expectation of the prediction. In the FE recognition literature it has been established that children with autism can recognise expressions such as happy, sad, surprise, disgust (Gepner et al., 2001). Production of FE is a new finding and adds to the literature of FE research.

Happy FE was produced by the HFA sample with significantly more clarity and intensity than all the other FEs produced by them within sample, except surprise. The production of disgust FE by the HFA sample was significantly worse compared to all the other FEs produced by HFA. Developmental literature on FE recognition claims that recognition of disgust is the hardest and it is achieved at a much later stage developmentally (Kolb et al., 1992; De Sonneville et al., 2002). Experiment 1 on FE production, which was carried out to establish baseline data, also reported that typically developing 6-10-year-olds are poor at production of disgust. The behaviour of the HFA sample for production of FE so far is in-line with previous research on FE recognition i.e. recognition of happy is reported to manifest earliest and is recognised most efficiently and recognition of disgust is most difficult and achieved at a much later developmental stage (Kolb et al., 1992; Herba and Phillips, 2004). The same pattern was observed here for production of FE by HFA i.e. happy was easiest to produce and disgust was hardest without any context or clues. As stated earlier although the HFA sample produced FEs which on average scored above zero on the Likert scale they were significantly worse compared to MC in the production of all FEs except fear on demand. Both the groups produced fear FE with low intensity and clarity, with the HFA sample scoring on average less than MC but this difference was not significant.

The second prediction was that HFA sample will produce happy and sad FEs at the same level as MC but will be significantly different from MC for complex emotions. The data presented here shows that although the HFA sample can produce all FEs they were significantly worse than MC in production of happy and sad FEs but were similar to MC in production of complex emotion, fear; resulting in rejection of second hypothesis.

Recent research in FE recognition has successfully demonstrated that children with autism can recognise happy, sad (Gepner et al., 2001) and fear (Spezio et al., (2007) FEs at a level similar to controls. Adolescents with autism can imitate happy and angry FEs at a level same as controls with explicit instructions. Data presented here from FE production with explicit instructions shows that performance of the HFA sample for all FEs are significantly worse than for MC, bearing in mind that the control sample here are of same CA and IQ and are matched on one-to-one basis. This is a new finding enriching the present literature of FEs from a production perspective. A parsimonious conclusion can be that the HFA sample performs at a significantly lower level of accuracy compared to controls but uses a similar mechanism except for fear.

Reviewing the between-group and within-group data it can be concluded that HFA children can produce FEs. Nevertheless performance is significantly worse than MC even for simple FEs like happy and sad. In a typical population it has been demonstrated that infants as young as 7-month-olds can reliably discriminate happy and sad FEs. Recognition ability of happy FE develops at a very young age for typically developing infants (Nelson and Ludemann, 1987) and reaches adult level of expertise at age of 6 (Kolb et al., 1992). Production of happy FE in children aged 3-5 years has been reported to be superior to all the other basic expressions (Field and Walden, 1982). At present the maturity age for production of happy FE is not available in the literature so concrete claims cannot be made. However, it is clear that HFA children aged 9-15 have not reached the adult level of expertise for production of happy FE. Even if this is true, it is obvious that the HFA sample, like MC found production of happy FE the easiest task. It is evident from the results that the HFA sample follows a similar behaviour pattern for happy, sad, angry and surprise; albeit significantly delayed.

FE recognition literature clearly indicates that happy FE is recognised by autism samples with accuracy similar to that of MC (Spezio et al., 2007). Hobson (1986) reported that children with autism were significantly worse than MC in matching emotion vocalisation and gestures to FEs. However, the study does not indicate performance of specific FEs which would have been beneficial because the literature clearly emphasises differential performance for each FE. Even when the overall HFA performance is significantly worst than controls it is possible that performance of specific FE is very similar to the controls. In fact, later research which has looked at specific FE recognition performance (Gepner et al. 2001; Spezio et al., 2007) has reported exactly this. Furthermore, research testing individuals with severe autism has not found the ability to recognise happy FEs (Celani et al., 1999) primarily because of profound autism in these individuals is compounded with learning difficulty. In those cases it is difficult to separate if the deficit is because of autism or the learning difficulty. On the whole, the finding of happy FE production on demand by HFA sample reported here is in addition and in accordance with recent FE recognition literature.

The performance for fear and disgust in the HFA sample is atypical. Production of fear FEs is on par with the MC whereas production of disgust FE is profoundly worse. Fear is a complex emotion and for HFA should be hard to produce; in contrast it is MC who perform poorly for fear FE. As stated in experiment 1 on FE production, the two expressions, fear and disgust, are difficult to produce without any explicit context or clues. The data of the MC in the present experiment is in-line with the developmental data for FE recognition (Kolb et al. 1992; De Sonneville et al. 2002). For MC it is difficult to self induce fear and disgust emotions. From the data one can claim that HFA participants also find it difficult to self induce disgust emotions. Performance for fear is also worse, although is not significantly different to MC or other FEs produced within group. One conclusion can be that the HFA sample, although significantly less expressive than MC, have similar behavioural pattern especially for fear emotion. This is contrary to the pattern of behaviour of individuals with autism in FR and FE recognition; where even when accuracy is achieved to similar level as MC the strategy used is atypical (Hobson et al. 1988) or there is a speed accuracy trade off (Behrmann et al. 2006). In the case of FE production, it appears that strategy used by the HFA sample is similar to MC, although performance is at a significantly lower level. Field and Walden (1982) tested 3-5-year-olds for production and discrimination of FEs. Children's ability to produce FEs was superior to their ability to discriminate. The ability to label emotions has also been claimed to be superior to recognition. If for typically developing children producing FE is easier than labelling, one can speculate that perhaps using a FE recognition paradigm which is the main tool of investigation in literature ~~in case of an autism population~~ is not the most suitable tool to investigate social deficits. However, it is evident from previous research in this field that the FE recognition paradigm has been the main tool because of confounding factors including difficulties in recording and scoring (Herba and Phillips, 2004), ethical constraints, arising due to filming children, and limited objectivity of scoring such video data. The investigations reported in this thesis highlight that production of FE is a more suitable paradigm for exploring deficit in social functioning.

One assumption is made here in the absence of explicit context that participants are self inducing the emotions in order to produce the FEs. This assumption holds both for the sample groups. Since I did not test participants for self induction of emotion I cannot claim with absolute certainty that participants self induce specific emotions in order to produce FEs. It is a speculation made based on evidence from FE recognition and social communication literature that in order to produce a FE, individuals are bound to experience the emotions albeit to a limited extent (Ekman 1997).

10.4.2 Labelling emotion of the character in the story condition

Secondly, a short scenario was presented each highlighting an emotion and the task was to label the emotion in the story and then produce the FE that would best display the emotion. It was thought that instead of providing the labels to participant, if they were asked to provide the labels then they would have to engage in the context situation cognitively, which may facilitate the induction of the emotion and further support production. It also gave me an opportunity to investigate the ability of the HFA samples to label emotions in context.

There was no significant group difference in labelling the emotion in the story condition, so the final prediction proved correct. The literature demonstrates that individuals with autism are better at labelling emotions than recognising especially the individuals with high-functioning autism (Oznoff et al. 1990). This was certainly true in the present experiment. The MC were particularly good at labelling the fear emotion in the story condition and the score for fear was highest for this sample. All emotions labelled by HFA and MC were at a similar level to each other, showing that the HFA sample are really good at labelling emotions in the story.

It can be concluded that as far as labelling emotions in story scenarios are concerned, HFA do not differ from matched control children. The impact of socialisation and display rules on labelling of emotions has been discussed under the previous experiment on FE production. For instance, the social norms dictate that the anger emotion is most likely to be disguised by the person experiencing the emotion and part of common socialisation may be learning not to display the anger emotion as well as learning not to be bothered by unimportant situations or disguise it if the person is actually feeling angry (Reichenbach and Masters, 1983). As mentioned previously, the consequence of such training is that when a person should feel angry and the labelling of the emotion should be 'anger' it gets misjudged for some other emotion; most commonly sad. The data presented here indicates that HFA children conducting themselves in mainstream schools in the UK are learning these socialisation skills and are able to apply them, albeit in simplistic scenarios under control conditions. It should be noted here that real life is far more complex than the experimental conditions created in this study as in real life single emotions do not present themselves in a simplistic manner, more often we come across complex emotions and or various combinations of simple emotions are presented. Also this study only tested very high functioning children with autism who, because they are in mainstream school, receive a lot of support and training in social skills thus impacting their knowledge and understanding of socialisation and display rules. A final point to note is that the participants tested here were on average of high verbal ability (VIQ = 100 on average) and in the past verbal ability has been claimed to have an impact on labelling FE recognition ability (Ireson and Shields, 1982; Brown and Dunn, 1996). This can be confirmed here as participants with high verbal ability have been shown to be better at labelling the emotion.

10.4.3 FE production with context

Participants were asked to produce the FE that best displays the emotion they labelled in the story condition. HFA children were significantly worse than MC in production of all the FEs within context. This is a new finding and adds to the literature because HFA children 9-15 years of age have not previously been presented with context and asked to produce FEs.

Context did not significantly improve the performance of HFA children in comparison to production FEs without context. Production of fear and disgust did improve but failed to reach significant levels of difference. This was probably due to the variance in the data both before and after context.

Context improved the performance of MC for all FEs, of which happy, fear and disgust improved remarkably. Happy and fear FE improved significantly with context, production of disgust also improved immensely but failed to reach level of significance, perhaps because of the variance in the data. Production of fear and disgust, which was difficult without context improved with context, in the matched sample. The data for the MC is in line with the developmental data for FE recognition discussed previously.

The production of sad and angry FEs by the HFA sample deteriorated with context and went down by nearly one point on average on the Likert scale of 1 to 7. This was similar to the performance of typically developing children 6-10 years of age, where context lowered performance of sad and anger FEs. In the MC, performance for sad FE remained stable with context and production of angry FE improved very slightly, not a significant improvement. As discussed previously, explicit context actually moderates sad and anger behaviour (Reichenbach and Masters, 1983). On examination of the HFA data for sad and anger FEs, it can be concluded that context moderated the FE production in the HFA sample, just as in typically developing children 6-10 years of age. MC, 11-15 years of age were less affected by context, especially for sad and angry FEs. Perhaps this is because their internal self moderation is effective even when self inducing FE and they are more aware of 'display rules' which are functional even when naturally inducing emotions. As a result they are more 'socially aware' of what is socially acceptable and do not produce the intense FE of sad and anger which they may later need to moderate to confirm what is socially acceptable.

The HFA sample has an atypical behaviour pattern for the fear emotion. Context is supposed to make production of fear and disgust FEs easier in terms of accuracy, clarity and intensity but fails to do this in the HFA sample, especially for fear FE. Fear FE was difficult to produce on demand for HFA children, labelling of the fear emotion was on par with MC however, production within context did not improve significantly. Labelling improved production of disgust although this failed to reach levels of significance because of the variance in the data. Taking the data for fear FE and the behaviour for other FEs into consideration, it is clear that children with HFA are impaired in fear perception. This is discussed in detail later in general discussion chapter.

Chapter 11

General discussion

Abstract

This final chapter summarises the findings of the thesis in two parts. It discusses individual and joint findings and themes from the experiments of inner outer FR and the two experiments of FE production and emotion labelling.

Following a summary of results and how these affects hypotheses the main questions discussed will be as follows:

1. *What causes the high level of accuracy in inner face recognition? What causes the difference in performance when full and inner faces are interchangeably available during learning and recognition?* Holistic face processing strategy in its entirety and the perceptual sameness caused due to the stimuli used will be considered.

2. *Why are children with autism poor fear facial expression production, whereas their ability to process faces holistically is spared?* The hypotheses for FR and FE impairments in autism presented in chapter 6 will be considered within the framework of FR models in explaining the findings of the experiments.

Inner-outer face effect and holistic face processing

11.1 Summary of results

The first part of this thesis investigated FR and holistic face processing in typically developing children 5 to 10 years of age. The inner outer face paradigm was used for this investigation and children were presented only the inner face both during learning and testing.

The results of the inner outer face effect show that 5-10-year-olds have no difficulty in processing inner face only information when this is available. There is no perceptual difference in the stimuli between learning and testing phase (experiment 1, chapter 9). In fact, the accuracy for inner face only recognition is exemplary and supersedes performance of all other conditions. This is a new finding as previous research has not tested FR from inner face only information.

Adding or removing information from the stimuli initially presented for learning has some damaging effect on children's performance (experiment 1, chapter 9). Adding the outer face during the recognition phase deteriorates the performance and the accuracy for inner to full face condition remained stable with age. This is a new finding as previous research has not presented inner face only information at the initial learning stage. Removing the outer face was not as detrimental to performance, and accuracy improved significantly with age for this condition. This finding is in accordance with previous research (Want et al., 2003; Bonner and Burton, 2004).

The inversion effect for inner face reported in this thesis is similar to the full face inversion effect reported previously (experiment 2, chapter 9). This is in accordance with previous research (Yin, 1969; Valentine, 1988).

When children have full and inner face information for learning accuracy for full face was significantly better from the full face information (experiment 4, chapter 9). This is a new finding as previous research has not presented full and inner face together for learning.

Older children are significantly faster than younger children in FR tasks (Experiment 4, chapter 9). This is in accordance with previous research (Want et al., 2003).

11.2 Support for hypotheses

The first hypothesis predicted that older children will be significantly better than younger children in all the conditions of this experiment. It is partly supported by the results of experiment 1, chapter 9.

My second hypothesis predicted that FR from inner face will be equivalent to FR from full face findings reported in the literature. This was not supported as FR from inner face only information was higher than that reported in the literature for full face (experiment 1, chapter 9).

My third hypothesis predicted that older children will be significantly better at the full to inner face recognition condition. This was supported by the results of experiment 1, chapter 9.

My fourth hypothesis predicted that children will be significantly better at FR from upright inner face compared to inverted inner face. This was supported by results of experiment 2, chapter 9.

My fifth hypothesis predicted that FR from full face and inner face will be equivalent for accuracy. This was not supported by the results of experiment 4, chapter 9 which showed opposite levels of performance for full and inner recognition.

My final hypothesis predicted that older children will be significantly faster than younger children for the FR task, and this was supported by the results of experiment 4, chapter 9.

The 'encoding switch hypothesis' presented by Diamond and Carey, (1977) has been continuously challenged and the age of the 'switch' progressively lowered by FR research, firstly, to 9 years of age (Want et al., 2003), then to 7 years of age (Bonner and Burton, 2004), and finally to 4 years of age (De Heering et al., 2007). Turati et al., (2006) presented 1-3-day-old infants unfamiliar inner faces both in habituation and preference phases. One of the conclusions was that infants can discriminate faces on the basis of inner face only information, thus questioning the 'encoding switch' hypothesis. To my knowledge previous research investigating FR in children and employing the inner outer face paradigm has not used inner face only information during both learning and recognition phases in 5-10-year-olds. The experiments reported in this thesis found conclusive evidence of 5-10-year-olds recognising faces from the inner face only information. The accuracy levels indicate the ease with which participants performed this part of the task. The inversion effect confirms use of holistic face processing of the inner face stimuli, thus further challenging the 'encoding switch' hypothesis.

11.3 *What causes the high level of accuracy in inner face recognition? What causes the difference in performance when full and inner faces are interchangeably available during learning and recognition?*

11.3.1 Methodological issues

Turati et al., (2006) proposed a hypothesis to explain the inner-face processing efficiency in infants: the *perceptual sameness* hypothesis. The authors proposed that if infants are habituated to the full face and then preference is examined with only outer or only inner face, there is an alteration in perceptual appearance, consequently affecting recognition. It was concluded that tasks using such stimuli merely demonstrate an infant's inability to detect perceptual similarity, rather than testing FR ability. The finding of this thesis (experiment 1, chapter 9) confirms that inner FR ability in 5-10-year-olds is optimal when they see inner face both during learning and testing. One may conclude that children aged 5 to 10 year olds are good at inner face recognition because of perceptual similarity of the stimuli during learning and testing. This means poor performance by children younger than 10 in past research on FR tasks could have been ameliorated to some extent by providing perceptually similar stimuli. It can further be concluded that perceptual difference between learning and testing is responsible, to a limited extent, for the difference in FR results between the outer, full and inner face conditions. Clearly, 5-10-year-olds have no difficulty in processing the inner face when inner face only information is present both for learning and recognition phases. Diamond and Carey (1977) claimed that factors which affect perceptual change of any visual display must influence face perception. Bonner and Burton (2004) also highlight the importance of face stimuli used in research and its impact on the findings. Taken together, the high levels of accuracy in inner FR demonstrated in this thesis can be attributed to perceptual similarity between the learning and testing stimuli. This reduces the task demands and enhances the accuracy of performance.

On the other hand, one may question if this result suggests that children executed feature-based processing because the inner faces presented during learning and testing were exactly the same stimuli. This doubt was discredited by the inversion effect observed for the inner face experiment (experiment 2, chapter 9).

Previous research has demonstrated the classic inversion effect in 5-year-olds (Brace et al., 2001). However, in that study full faces were used both for learning and recognition and the faces were presented with context, in a story condition. The present study differed from Brace et al., (2001) in two respects: firstly that only inner faces were presented both during learning and recognition and secondly that the design of the experiment was faces presented in isolation and not in context. Nonetheless, children as young as five years of age demonstrated the classic inversion effect, thus adding to the previous research and enriching the literature. Inversion effect has been a strong indicator of holistic processing as well as configural processing. The findings of this thesis provide evidence that 5-year-olds can process unfamiliar faces, executing holistic face processing strategies because they succumb to the inversion effect. All aspects of holistic processing will be considered comprehensively in the next section. At this stage we can conclude that holistic processing for inner face stimuli is partly demonstrated by the inversion effect.

Perceptual similarity of stimuli is used to explain many of the existing results in the literature. This would mean that perceptual difference in stimuli would show a similar deterioration in performance for full to inner face and inner to full face conditions. However, the findings with 5-10-year-olds reveal that performance for the full to inner face condition follow a different pattern to that for the inner to full face condition. Typically developing 5-10-year-olds when they learn inner face and are asked to recognise full face make the least improvement. The performance of 7-8-year-olds for this condition dipped even further, making their performance significantly worse than 9-10-year-olds. The fact is, both full to inner face and inner to full face conditions involve perceptual variance between learning and recognition. The simple question is: why should these two similar variances produce drastically different results? Perceptual similarity between two stimuli is insufficient to explain all the results obtained in this thesis for the inner outer face effect. In order to explain the findings completely, holistic face processing strategy in its entirety is now considered.

11.3.2 Holistic face processing strategy

The inversion effect as a paradigm is frequently implemented to investigate holistic face processing and in those studies full face is mostly used as the stimulus (Diamond and Carey, 1986; Valentine and Bruce, 1988; Valentine 1988; Collishaw and Hole, 2002). In this thesis the inversion effect for inner face is demonstrated in children as young as 5 years of age. This can be taken as evidence for holistic face processing and is in accordance with existing literature.

Research investigating holistic face processing using a composite face paradigm (Mondloch et al., 2007; De Herring et al., 2007) or whole-part face paradigm (Tanaka and Farah, 1993) only considers glueing inner face parts together into a gestalt. Holistic face processing does not only mean glueing internal features together, it also means glueing the inner face to an external contour (Young et al., 1987; Sinha and Poggio, 1996). This was reviewed in chapters 2 and 7. Studies investigating familiar FR report that if one familiar inner face and a different familiar outer face are put together the resulting stimulus is perceived as a novel face (Young et al., 1987; Sinha and Poggio, 1996). Instead of cropped inner or outer faces Campbell, Walker, Benson, Wallace, Michelotti and Baron-Cohen, (1999) presented faces with either the inner or outer parts blurred. The authors concluded that when the outer face was available, either clear or blurred, it was processed automatically and affected the accuracy of participants in the FR task. The study claimed that outer face information continues to impact FR until 15 years of age. This means that the 'encoding switch' proposed age of 10 years was once again questioned and pushed to 15 years.

The three conditions for investigating the inner outer face effect used in this thesis gave me the opportunity to examine holistic face processing of inner face and the effect of novel external contours. The data for the inner to full face condition showed that 5-10-year-olds cannot recognise a previously-seen inner face 30% of the time. It can be concluded that for unfamiliar faces if outer face is available only during testing, it gets glued to the previously learnt inner face and the stimulus perceived as a new face. This indicates that in unfamiliar face processing, the outer face acts as a salient cue. If the outer face information is available it will in some respect interfere with the recognition performance. This is exactly the same as the finding reported by Campbell et al., (1999) for familiar faces i.e. information from outer face if available will be processed, and this thesis extends the finding to unfamiliar face stimuli. In conclusion, the data presented here indicates that 5-10-year-olds can execute an holistic face processing strategy, both in the case of glueing inner facial features together and glueing inner face with an external contour.

The experiments reported under chapter 9 indicated that an holistic processing strategy in its entirety can only be inferred when not only inner face processing is tested but also when inner face and external contour glueing is tested. Without testing the glueing of inner face with external contour De Herring et al., (2007) concluded that by 4 years of age children have mature holistic face processing ability. The two holistic face processing strategies discussed here have quite different impacts on the accuracy. Ability to glue inner face features together improves accuracy of FR. However, tendency to glue inner faces to external contours deteriorates the accuracy of FR. The finding from this research clearly demonstrates both types of the holistic face processing strategies operating in 5-10-year-olds.

Experiment 4 (chapter 9) demonstrated that although 5-10-year-olds can recognise faces from inner face only information, they are better at assimilating information from full faces and are able to process full faces significantly faster. This suggests that for unfamiliar faces children up to 10 years of age prefer full face stimuli and are able to process these for recognition more efficiently. Considering all the inner outer face effect data it is clear that the entire holistic face processing strategy does not mature fully until 10 years of age. The 'encoding switch' hypothesis has been continuously challenged and age of 10 discredited with researchers reporting a progressive lowering of age. The research of this thesis shows that Carey and Diamond, (1977) were partially right. It is evident that for children outer face is a salient cue, enhancing performance in terms of both accuracy and speed. If information from full face or outer face is available, children tend to focus on them more, however, in the absence of outer face or full face 5-10-year-olds are perfectly capable of recognising faces from inner face only information. This is in accordance with previous research for familiar faces (Campbell et al., 1999) where children were able to recognise familiar faces from inner face information. The results highlight that seeing a face in more than one format does not enhance FR accuracy. The difference between processing familiar and unfamiliar faces previously observed is therefore not exclusively due to previous exposure to the familiar face with and without hair.

The reaction time data highlight that younger children are significantly slower than older children for full FR and inner FR. This means that FR and holistic face processing is still developing and has not reached adult levels by the age of 4 or 6 as is claimed by previous research (De Heering et al., 2007; Mondloch et al., 2007) .

Even when accuracy is achieved at adult level 5-7-year-olds take significantly longer than 9-10-year olds, signifying that the holistic processing strategy is still developing.

11.4Inner-outer face effect in HFA children

11.4.1 Summary of results

This thesis was also investigating holistic face processing strategy in HFA children using the inner-outer face paradigm, with participants having inner face only information. It was also investigating the ability of HFA children to label and produce FEs and comparing this ability with matched controls.

The results of the inner outer face study show that the HFA sample was not significantly different to matched controls. This is in accordance with previous research (Rondan et al., 2003; Behrmann et al., 2006; Wilson et al., in press). HFA children have no difficulty in processing inner face information and they are not significantly different to matched controls in this condition (experiment 2, chapter 9). The accuracy for inner face only information was exemplary and superseded performance for the other conditions, just like matched controls. This is a new finding as the previous research has not tested FR from inner face only information.

Adding or removing information from the stimuli had the same damaging effect on the performance of the HFA sample and the matched controls (experiment 2, chapter 9). Adding outer face deteriorated performance of the HFA sample to the same extent as the matched controls. This is a new finding, as previous research has not presented inner face during learning and asked participants to recognise the same inner face with a novel external contour. The result reported in this thesis is in contrast to previous hypotheses regarding the superior local level processing and avoidance of global perception within an autism sample (Frith and Happé, 1994; Mottron and Burack, 2001).

11.4.2 Support for hypotheses

The first hypothesis predicted that the HFA sample will not be significantly different to the matched controls. This is supported by the results of experiment 2, chapter 9.

The second hypothesis predicted that the HFA sample will be significantly less sensitive to inner face with novel contour and as a result the accuracy for inner to full face condition will be significantly better for the HFA sample. This was not supported, as the accuracy of the HFA sample and matched controls were very similar for the inner to full face condition.

11.4.3 Holistic face processing is spared in HFA children

Recent research has failed to find a significant difference between the accuracy of performance of children with autism and controls. This has been true especially with high-functioning individuals with autism and adults with autism (Behrmann et al., 2006; Wilson et al., in press). Even the seminal study by Hobson et al., (1988) which tested adults with autism for FR reported that performance for identity recognition was as good as the control sample. The authors concluded that the "autism sample can recognise something about identity but fail to process the feelings expressed in a face stimulus". In the present research, I come to the same conclusion: HFA children have no difficulty in recognising a person's identity in experimental conditions. The FE findings which establish a deficit in FE production are presented later.

The HFA sample and matched controls were both significantly better in the inner to inner face condition than the other two conditions. This clearly reveals that the HFA sample participating in this experiment was able to process inner faces and use strategies that were similar to the matched controls. Moreover, the ability to process inner faces was at the same level as the matched controls. The first aim of this experiment was to ascertain if HFA sample participating in the FE production task could process inner face only information. It can confidently be concluded that the HFA sample can proficiently process inner face only information. This is a new finding which adds to the literature available so far, as in previous research inner face has not been presented for learning.

It is frequently reported that individuals with autism are very good at local level processing and are not influenced by the global theme or meaning (Frith and Happé, 1994; Mottron and Burack, 2001). The famous *embedded figure task* has been used to demonstrate this local bias (Shah and Frith, 1983). The *weak central coherence* hypothesis is centred on this assumption and research reviewed by Frith and Happé, (1994) confirm this assumption. Superior local level processing and avoiding global perception was also suggested by Mottron and Burack, (2001). In this thesis the second prediction (experiment 3, chapter 9) was based on this principle that the HFA sample would be significantly less sensitive to the effect of novel external contours on inner face processing. However, there was no significant difference between the performance of the HFA sample and the matched controls for the inner to full face condition. The HFA sample participating in this experiment was as sensitive to the novel external contours as the matched controls. This is an indication that HFA children were processing face stimuli at a global level for identity and not using feature based processing. Conceivably, this was because HFA children in this experiment had developed alternative processing strategy by the age of 9-15 years. The accuracy measurement failed to pick up any subtle differences in FR mechanisms used by HFA children who are in mainstream school and are receiving intense training and support in order to negotiate their social world. Nonetheless, the finding in this experiment is that both groups were equally poor at recognising inner faces when inner faces were presented within novel contours. The results of FR indicates that contrary to assumptions of the WCC theory and superior local level processing theory HFA individuals can bind together stimuli such as face stimuli, are influenced as much as MC by global theme and do not exclusively operate local level processing when recognising faces.

It is evident that HFA children execute an holistic face processing strategy and are affected by both aspects of holistic face processing. As stated previously, holistic face processing of inner face only information enhances FR in a typical population and the results for the HFA sample demonstrated the same effect exists with the autism population. Holistic face processing resulting in glueing external contour to inner face deteriorates FR in a typical population and the results of the HFA sample demonstrated the same effect.

In conclusion, the inner-outer face effect investigated with HFA children who were individually matched for CA and IQ confirms that in experimental conditions children with autism can process faces for identity at the same level as controls. Furthermore, this is not achieved using piecemeal or feature based processing and children with autism are as sensitive to global information as the typical population. However, this research was only recording accuracy for the autism sample and previous research using reaction time measures, eye tracking methods and Spezio et al.,'s (2007) novel 'bubbles' design has demonstrated that the strategy used by children with autism is atypical. It should also be noted that the FR task was a very simple task where only one face was presented at a time with no other distractions. Real life situations are very different as demonstrated by Riby et al., (2008). Children with autism were significantly poorer than matched controls in detecting face stimuli and their interest wasn't held by the face stimulus for long after detection. Juxtaposing these two findings it can be inferred that children with autism are capable of holistic face processing in simplistic experimental conditions. When rich stimuli are presented the ability to execute holistic processing using alternative strategies deteriorates significantly.

11.5 FE production and labelling in HFA children

11.5.1 Summary of results

Children from both the groups demonstrated that they can use all the relevant facial muscles required for FE production and these muscles are under complete voluntary control of the individual.

The results of the FE production on demand task show that the HFA sample was able to produce the six basic FEs on demand. This is a new finding as previous research has not tested HFA children for production of FEs and it adds to the literature of FE research.

Secondly, the results show that the HFA sample was significantly worse than the matched controls in production of all FEs on demand except for fear. Although both the groups produced fear FE with low intensity and clarity, the HFA sample scored less on average than the matched controls, but this difference failed to reach significance. This is a new finding as previous research has not tested HFA children for production of FEs on demand. This is in accordance with the FE recognition literature (Week and Hobson, 1987; Celani et al., 1999; Spezio et al., 2007) as well as implicit imitation literature (McIntosh et al., 2006).

Thirdly, the results show that the HFA sample was significantly worse than matched controls in production of all FEs within context. Performance of the matched controls for fear improved significantly within context. The HFA sample, however, failed to improve their performance for fear FE production within context. This is a new finding as previous research has not tested HFA children for FE production within context. This is also in accordance with the FE recognition and implicit imitation literature.

Finally, the results show that there was no significant difference between groups in labelling emotions in the story condition. This is in accordance with previous research (Oznoff et al., 1990).

11.5.2 Support for hypotheses

The first hypothesis predicted that the HFA sample will produce happy and sad FEs as a minimum. The results of the FE production on demand task (experiment 2, chapter 11) were beyond the prediction of the first hypothesis. For the HFA sample production of happy FE was best and production of disgust was the worst significantly in terms of clarity and intensity.

The second hypothesis predicted that the HFA sample will produce happy and sad FEs at the same level as matched controls but will be significantly different to matched controls for complex emotions. The results of experiment 2, chapter 11 show that HFA children's production of simple FEs such as happy and sad were significantly worse and production of complex FE such as fear was same as the matched controls, resulting in rejection of the second hypothesis.

The final hypothesis predicted that the HFA sample will not be significantly different to matched controls in labelling of emotions and was supported by the results of experiment 2, chapter 11.

FE recognition literature in typically developing children clearly states that happy FE is the easiest to recognise and develops first while disgust FE is the hardest to recognise and emerges quite late developmentally (De Sonneville et al., 2002). HFA children show a similar pattern of behaviour for FE production: happy is easiest to produce with and without context and disgust is the hardest to produce especially without context. When HFA children are asked to produce FEs on demand the pattern of behaviour for happy, sad, angry, surprise and disgust are similar to the matched controls, albeit at a significantly lower level. The production of fear FE by the HFA sample is atypical, with the production being the same as the matched controls when there is no context and production being significantly poorer when there is context. The findings of this thesis as regards fear FE will be discussed later on.

Disgust FE produced by the HFA sample improved with context, whereas sad and angry FEs appear to be negatively affected by context, however none of these reached levels of significant difference compared to production on demand. The performance for fear FE did not improve with context at all. Matched controls' performance within context improved significantly for happy and fear FEs. Performance for disgust FE improved remarkably but failed to reach significance because of variance in the data.

Why are children with autism poor fear facial expression production, whereas their ability to process faces holistically is spared?

11.6 Dissociation between FR and FE production mechanisms

The results of the HFA sample reported here argues against a generalised failure to process faces and points towards a dissociation between mechanism for face processing for identity and FE production. The cognitive models of face processing discussed in chapters 1-4 make this distinction very obvious. The findings are in accordance with previous research FE recognition literature (Hefter, Manoach and Barton, 2005; Teunisse and de Gelder, 1994) and the finding extends the literature to the production of FEs. By deduction it can be claimed that identity recognition, FE recognition and FE production are all dissociable in the autism population. This is consistent with the models of FR that propose divergent processing streams for the perception of FE and facial identity (Bruce and Young, 1986). The results of the studies reported here suggest that the processing deficit in HFA individuals can affect the divergent streams independently and variably rather than a major assault upstream affecting everything. The results of the inner outer face effect can be an indication of more downstream impairments because the children executed both aspects of holistic face processing. Alternatively, they indicate that HFA children 9-15 years of age have developed alternative strategies which enable them to process faces for identity at the same level as the matched controls. Neurophysiological evidence backs the latter argument. Baron-Cohen et al., (1999) reported that individuals with autism put a greater processing load on the temporal lobe structures instead of using the amygdala. It should be noted that in contrast researchers (Herba et al., 2006) have demonstrated the impact of FE on FR processing with typical children, thus challenging Bruce and Young's, (1986) model. Juxtaposing such claims and the result of studies reported in this thesis, it is evident that the face processing and facial expression processing systems, although divergent, operate in continuous feedback and feed-forward loop. Thus the modules which Bruce and Young, (1986) claimed to exist when processing face stimuli, certainly do not operate in complete isolation, rather in continuous interaction with each other.

The results of this thesis are even more consistent with the model of a distributed neural system for face perception (Haxby et al., 2000). This model proposes a *core system* which is hierarchical and an *extended system* which is interactive both within itself and with the *core system*. According to this model FR is handled by the *core system* and FE more by the *extended system*. If that is the case then in HFA children it would appear that the *core system* is operating at a level similar to typical population.

In HFA children deficits in FE labelling and FE recognition are not a generalised deficit, rather a differential level of performance for different FEs. Firstly, in the typical population it has been demonstrated that performance for all FEs are not uniform. Children behave differently for different FEs (Gosselin, 1995; Camras and Allison, 1985) with performance for happy maturing earliest and disgust emerging much later in life (Kolb et al., 1992). This is the same in HFA children who perform differently for different FEs and the findings of this thesis regarding FE extend this conceptualisation to the HFA population. This would imply dissociation between the six basic FEs, which will be covered in the next section.

Previous research has demonstrated the FR and FE recognition are dissociable in autism population (Hefter et al., 2005; Hobson et al., 1988; Teunisse and de Gelder, 1994). The results presented here suggest that face processing for identity is dissociable to production of FEs. For HFA the identity processing is functioning at a level similar to the matched controls for faces presented in experimental conditions. This leads to the conclusion that maybe holistic face processing is spared in HFA children. Alternatively, HFA children may have developed alternative strategies to process faces for identity. This dissociation is a new finding in autism population and extends the present literature.

11.7 Rationale for impairment in Fear processing and FE production

As mentioned earlier production of happy, sad, angry, surprise and disgust follows a pattern of behaviour which is very similar to the matched controls, nonetheless at a significantly lower level. This is in accordance with the FE recognition literature (Week and Hobson, 1987; Celani et al., 1999; Spezio et al., 2007; Klin et al., 2002). Production of fear FE is atypical and needs further consideration. The amygdala is responsible for fear perception and processing and hypoactivation of the amygdala in autism sample was reported by Baron-Cohen et al., (1999). Dawson et al., (2004) tested 3-4-year-olds with autism and reported that early brain responses to fear FE were slower to matched controls. In addition the study demonstrated both delay in processing and abnormal scalp topography, indicating a compromise in speed and cortical area of processing. As stated in chapter 6 *the amygdala theory* (Baron-Cohen et al., 2000) argues the idea that individuals with autism use an alternative neural system for processing FEs because the amygdala is not functioning. This leads to atypical performance for FE recognition. Non-function of the amygdala predominantly means failure to process fear leading to impaired fear perception. Research in neuroscience has reliably and consistently linked the amygdala to fear processing and it is the only emotion linked to one specific brain area (Phan, Wager, Taylor and Liberzon, 2002). Behavioural and neurophysiological research has already established the vital role of the amygdala in fear processing and the effect of amygdala impairments in individuals with autism (presented in details in chapters 4 and 6). The *amygdala theory of autism* uses data from animal model, from amygdala lesion patients and from Asperger syndrome individuals, and infers that fear perception is impaired in autism. Juxtaposing previous literature with the results of this thesis it can be concluded that an impairment of amygdala also impacts on production of fear FE.

The second possible primary reason for the impaired fear FE production is 'lack of experience'. Campos, Frankel and Camras, (2004) claimed that emotion regulation is a two stage process; one, generation of the emotion and second, management or mismanagement of the generated emotion. According to the authors, development of emotion regulation is influenced by factors such as development of language and internalisation of social signals. Additionally, management of the generated emotion is, to a certain extent, influenced by social and cultural proscriptions and is actually learnt at a very early age from observation and interaction. Internalisation of social signals is in essence learnt from the primary carer by continuous observation and interaction. Camras, Oster, Campos and Bakeman, (2003) report that infants do not produce discrete negative emotions such as anger, fear and sad in the early stages of life and this is gradually learnt from social biofeedback. Social biofeedback refers to the process wherein the parent selectively exaggerates and mirrors the infant's expressions to help the infant shape their ability to produce discrete negative emotions. This hypothesis is supported by research which reports that maternal depression influences a child's perception of the sad emotion (de Haan, Belsky, Reid, Volein and Johnson, 2004) and children who are physically abused are hyper sensitive to anger perception (Pollack and Kistler, 2002).

If the developmental pathway for negative emotion recognition, understanding, labelling and production, is through learning from the primary caregiver, then how does this affect children with autism? Children with autism are known to be exceptionally poor at joint attention, gaze following and shared attention from a very early age (WHO, 1994) and do not orient to faces (Dawson et al., 1998). Osterling and Dawson, (1994) examined first birthday party home videotapes of children later diagnosed with autism. They found that in addition to impairment in shared attention, 1-year-olds attended less to people and failed to orient when their names were called. This suggests that children with autism fail to observe the primary caregiver and learn about negative emotions and FEs from social biofeedback, consequently not acquiring the discrete categories of all negative emotions and FEs. This in turn impacts the emotion regulation mechanism, finally affecting production of negative FEs. The results reported here suggest that production of negative emotions is impaired in HFA children, which is compounded even more for fear FE.

The final possible reason for impairment of fear FE is also related to a 'lack of experience', this time impacting on cortical specialisation. 'Social intelligence', as discussed in chapter 6, is our ability to 'read other minds' and negotiate our way successfully through the social world. Specific brain areas, namely the amygdala, OFC and STG have been demonstrated to be the site of social intelligence (Brothers, 1990; Baron-Cohen et al., 1999). Grossman and Johnson, (2007) claim that for the social intelligence neural circuits to develop and function at an expertise level, experience is mandatory. Boraston et al. (2008) similarly indicate that experience and expertise would hinder performance. Experience right from the time of birth is vital in joint attention and processing of faces, eye gaze, emotions, biological motions and the impact of human actions on objects. This line of argument accentuates the role of experience, by stating that it causes the generalised brain areas involved in common processing during infancy to specialise and fine tuned cortical regions involved in processing only social stimuli finally emerge. The authors also speculated the impact of experience with 'imitation' and 'reading other minds' on cortical specialisation, but due to lack of experimental evidence this could not be used to substantiate specific cortical specialisation. The cortical specialisation is crucial for the individual to function at the expertise level for faces and with experience these neural structures become more differentiated and specialised in their response properties. In the case of HFA adults it is already proved that the social intelligence neural circuit does not activate when performing emotion labelling tasks and as a result the performance is significantly worse compared to controls (Baron-Cohen et al., 1999). Instead, a greater processing load is placed on temporal lobe structures such as the STG. Taken together this is direct evidence of failure of cortical specialisation due to lack of experience with faces, eye gaze, joint attention, shared attention, biological motion at in individuals with autism. As a result alternative neural systems are used and a greater processing load is placed on alternative brain areas in autism population. These alternative neural circuits may be able to process and handle gross functions such as identity recognition, positive FEs recognition and labelling positive emotions. However, when it comes to complex stimuli such as negative FE recognition and production of FEs, these distributed cortical processing areas fail to function effectively. The cumulative effect of not learning discrete categories of FEs in early childhood and the lack of cortical specialisation results in a failure to produce FEs at a level similar to matched controls.

The experience-expectant and activity-dependent model proposed by Nelson, (2001) draws attention to the role of experience at a critical period for FR to develop. The role of experience in the development of expertise level face processing ability was also emphasised by Pascalis et al., (2002 and 2005) and Geldart et al., (2002). In conclusion for the face processing mechanism to develop and finally reach adult level of expertise experience is essential at the critical period. Shultz et al., (2005) infer that children with autism do not naturally orient to faces, participate in joint attention, shared attention or gaze following and the final result is failure of cortical specialisation and inability to process finer aspects of face stimuli.

11.8 Implications of this thesis

The results of inner outer experiments reported here suggests that typically developing children as young as 5 years old are susceptible to glueing face parts together and perceiving face as a whole. HFA children aged 11 to 15 demonstrated the same behaviour. This contradicts the WCC but is inline with experience-expectant face processing theory.

The results of this thesis indicate that HFA children attending main stream schools have a good understanding of emotions and *display rules* for emotions. They are able to use concepts of *display rules* and moderate their FEs for sad and angry which indicates that they understand the social norms of not displaying what one is feeling or rising above the situation.

This thesis however, only recorded accuracy response for most tasks which do not always elicit the difference in performance between typical and atypical populations. The inner outer face effect experiments reported here are ideal for testing holistic face processing. In future if the same experiments are carried out and reaction times as well as accuracy are recorded, it could illustrate quantitative differences in development and speed accuracy trade-offs both in typically developing children and children with autism. The results reported in this thesis highlight that HFA children of 9-15 years of age do not have any deficit in identity processing in experimental conditions when one face is processed at a time. However, they may have developed an alternative strategy to perform the task at the same level as the matched controls. In future younger, children with autism should be tested in order to infer the developmental pathway for FR and to further investigate the development of alternative strategies. The inner outer face effect designed to test participants in this thesis is simple and child friendly with minimal task demands. It would be an excellent paradigm to test younger children with autism and note accuracy and the reaction time data.

The experiments reported here did not investigate FE recognition ability. Future research exploring production of FE may consider investigating FE recognition in tandem in order to compare and correlate the recognition and production ability of individuals with autism.

FACS coding system takes into account the whole face and facial movement of multiple face areas in order to code for each of the six basic expressions. This thesis demonstrates that FACS is very effective in coding FEs. However, additional information such as only upper or lower face movement especially if testing autism population should also be recorded. This will enable the researchers to test the assumptions that autism population have defective gaze detection system and they tend to process mouth area more than eye region. Information of upper and lower face parts used to produce FEs was not coded separately in this research. However, such information would further reinforce theories such as social motivation and experience-expectant theory and future research should consider coding such information.

Face processing literature in autism population indicates that they use alternative strategies to accomplish face processing tasks (Klin et al., 2002; Joseph and Tanaka, 2003; Baron-Cohen et al., 1999). Eye tracking methods in the recent past have been used to demonstrate an atypical scanning pattern in the autism population (Klin et al., 2002; Riby et al., 2008). In future if eye tracking is used in conjunction with inner-outer face effect tasks then conclusive evidence of holistic face processing can be inferred.

Research with the autism population always involves comparing the performance of the autism sample with typical population. It is imperative that the diagnosis of autism is made either by using ICD-10:DCR-10 or ADI-R or ADOS. The present system in Britain is that a diagnosis for clinical purposes is reached by a multi-disciplinary team of psychiatrist, community paediatrician, teachers, educational psychologists and other professionals. Charman, (2006) vouched for clinical diagnosis reached by such a multi-disciplinary team and its validity. Nonetheless, it is possible that children diagnosed for clinical purposes may not meet the stringent criteria of the diagnosis for research purposes. Also, for the purposes of matching, both full scale IQ and CA has been used in the present research and each HFA child was individually matched. This has been very useful as it is allows comparison of data and examination of the differences caused primarily because of autism.

Future research investigating production of FEs may consider providing context and the FE labels, in order to explore participants' behaviour for production of FE and not how the 'character' in the story feels. This will allow us to examine the real differences in emotion between the autism population and matched controls as well as investigate the individuals' own feelings and expressions. Anecdotal feedback, specifically from children with autism in the FE production experiment, informed me that they failed to see the birthday party story as a 'surprise' scenario. Individuals with autism reported anxiety and disliking to the thought of someone 'in their own space' i.e. at their house. The present research did not examine difficulty in perspective taking and its impact on FEs and cannot comment on this. As individuals with autism have a deficit in perspective taking and theory of mind, story condition perhaps acts a confounding factor. A core element of production of FE is communication of the feeling and as the individual with autism has no desire to communicate or share, this may pose a challenge to FE production research.

Present research also did not record gender and actual age of participant. Only the age range such as 6 to 7 year olds was recorded for the inner outer FR investigation. This meant gender differences or impact of age could not be investigated here. Future research may consider recording more participant details such as gender and exact age on the date of testing.

Finally, Baron-Cohen et al., (1999) had recorded fMRI as the participants performed the 'mind in the eye' task and reported the alternative neural systems used for a FE recognition task. ERP or fMRI recording while participants are producing FEs may give us a better understanding of the role of the amygdala in FE production as well as support the investigation of whether alternative neural systems are executed for FE production.

11.9 Concluding remarks

HFA children attending mainstream schools have the ability to process inner face for identity, execute holistic face processing and label the six basic emotions at the same level as matched controls. This indicates that for identity processing HFA children do not use local level processing or piecemeal processing and do not see faces as collection of features, rather a complex configuration where the relation between the features is important as the features themselves. Production of facial expressions is significantly worse taking clarity and intensity into consideration. The pattern of behaviour for happy, sad, angry, surprise and disgust FE production is similar to matched controls and replicates the pattern of FE recognition. Children with autism have an atypical perception of the fear emotion and fail to use context to improve production of fear FEs. This is in complete accordance with existing literature on FE recognition and the neurophysiological literature on abnormality of amygdala in autism. Furthermore, it is evident that experience with faces, gaze direction, joint attention and shared attention are the corner stones for the development of individual's understanding of negative emotions. The results of the studies reported here reinforce the hypothesis of amygdala impairment in autism and indicate that alternative neural structures can only compensate for dysfunction of the amygdala to a limited extent. It also reinforces the recent claims that children with autism can process faces for identity (Wilson et al., in press). However, they fail to achieve the expertise in order to deal with complex aspects of the face stimulus.

The results of this thesis demonstrate that children 5-10 years of age can process inner faces if this is the only information available and can do so with as much efficiency as processing outer faces. This challenges the existing notion that typically developing young children cannot process inner face information and when they do process inner faces it is done on a featural basis. However for identity recognition, 5-10-year-olds prefer full face when this information is available and accuracy with full face is achieved much faster. The accuracy and speed of face processing continues to improve with age at least until 10 years, thus challenging the notion that holistic face processing is at adult level 4 years of age.

Chapter 12

Appendices

Appendix 1

Short stories for the emotion labelling task

1. John wanted a Harry Potter Lego set since he saw the first movie. His mother finally bought him the set for his seventh birthday.
   How does John feel?

   ____

2. Tom had a Thomas the Tank engine train set since he was very young. One day his friend Joe comes to play with him after school and breaks the engine and a track. This means Tom will not be able to play with the train set again.
   How does Tom feel? ___________

3. Sam dad buys him a blue BMX bicycle because Sam has done really well in school that year. Blue is Sam's favourite colour and he thinks it is the coolest bike ever.
   How does Sam feel? _______________

4. Josh has star chart at home and gets a treat when he collects 15 stars. One morning he refuses to get up and swears at his mother. His mother tells him over breakfast that he will loose 3 stars and he will not get any treat that week.
   How does Josh feel? ________________

5. Matthew goes swimming two days a week at his local swimming pool. One day as he is swimming in the big pool he finds something floating if front him.

When he takes a closer look he sees that is a piece of poo. He jumps out of the pool immediately.

How does Matthew feel?

6. Sarah does not like spiders and creepy crawlies. For a 'show and tell' Roz brings in her pet spider in a glass box which is hairy, black and huge. The spider is let out accidentally and everyone is asked to look for it.

   How does Sarah feel? __________________.

7. Helen has a pet hamster Fluffy that she spends a lot of time with and plays with her a lot. One morning she finds Fluffy dead in the cage.

   How does Helen feel? __________________.

8. It was John's tenth birthday, he comes home and as he walks through the front door he finds all his friends wearing party hats and they shout 'HAPPY BIRTHDAY JOHN'.

   How does John feel?__________________.

9. Jack sees a brown paper box at the bottom of the stairs in his house. He thinks that the box is empty and kicks it gently and a kitten jumps out of the box.

   How does Jack feel? __________________.

10. Mary gets an apple for her break; she takes it out and bites into it. But the apple was rotten from inside and tasted awful. Mary spits out the apple.

    How does Mary feel?__________________.

11. Libby and Salina are best friends spending a lot of time together at school and over weekends doing all the things they both enjoy. Libby also helps Salina at times with her home work. One day Libby tells Salina that she is moving to another town.

    How does Salina feel? _____________.

12. David does not like being alone in the dark. One evening he was playing in his room and all the lights suddenly went out. David called out for his mum but no one answered.

How does David feel?

Appendix 2

Stories to be rated by teachers

You are requested to read each story and then write how the emotion the character in the story would feel. You need to choose one emotion from the following

HAPPY SAD FEAR ANGER SURPRISE DISGUST

1 John wanted a Harry Potter Lego set since he saw the first Harry Potter movie. His mother finally bought him the set for his seventh birthday. John feels ______________

2 Tom had a Thomas the Tank engine train set since he was very young. One day his friend Joe comes to play with him and breaks a track and the main engine. Tom will not be able to play with the train set again. Tom feels ______________

3 Sam's dad buys him a blue BMX bicycle because Sam has done really well in school that year. Blue is Sam's favourite colour and he thinks it is the coolest bike ever. Sam feels ______________

4 Josh has star chart at home for good behaviour and gets a treat when he collects 15 stars. One morning he refuses to get up and swears at his mother. His mother tells him he will loose 3 stars and will not get any treat that week. Josh feels ______________

5 Matthew goes swimming two days a week at his local swimming pool. One day as he is swimming in the big pool he finds something floating if front him. When he takes a closer look he sees that is a piece of poo. He jumps out of the pool immediately and feels ______________

6 Sarah does not like spiders and creepy crawlies. For a 'show and tell' Roz brings in her pet spider in a glass box which is hairy, black and huge. The spider is let out accidentally and everyone is asked to look for it. Sarah feels ______________

7 Helen has a pet hamster Fluffy that she spends a lot of time with and plays with her a lot. One morning she finds Fluffy dead in the cage. Helen feels ______________

8 It was John's tenth birthday; he comes home from school with his mum thinking that the house is empty. He goes into the lounge and a puppy jumps he walks through the front door he finds all his friends wearing party hats and they shout 'HAPPY BIRTHDAY JOHN'. John feels ________________.

9 Jack sees a brown paper box at the bottom of the stairs in his house. He thinks that the box is empty and kicks it gently and a kitten jumps out of the box. Jack feels ________________.

10 Mary gets an apple for her break; she takes it out and bites into it. But the apple was rotten from inside and tasted awful. Mary spits out the apple feeling ___________________.

11 Libby and Salina are best friends spending a lot of time together at school and over weekends doing all the things they both enjoy. Libby also helps Salina at times with her home work. One day Libby tells Salina that she is moving to another town. Salina feels _______________.

12 David does not like being alone in the dark. One evening he was playing in his room and all the lights suddenly went out. David called out for his mum but no one answered. He felt _________________.

For the following statements please delete the appropriate:

1. All the scenarios above are simple and easy for children 6 years of age and above to understand YES/NO.

If no then please specify which story will children find difficult (put the number of the corresponding scenario/s) __________

Please suggest ways in which these scenarios can be made more children friendly

____

____

____

____

2. All the words used in the stories above are familiar for children 6 years of age and above YES/NO

If no then please specify which word(s) children will find difficult

____

If possible please suggest alternative words that the children 6 years of age would be familiar to

____

3. Any other comments

Appendix 3

Data coding sheet

Participant	Expression	Face	Shoulders	Hands	Other parts of the body (specify)

Appendix 4 Data coding sheet 1

Participant no. : ____________

PART 1

Facial expression production on demand: Please label the expressions and rate them

1 = mild, 7 = exaggerated

1. Expression demanded –
   Expression produced –
   Rate the expression produced on a scale of 1 to 7
   1 2 3 4 5 6 7

2. expression demanded –
   Expression produced –
   Rate the expression produced on a scale of 1 to 7

   1 2 3 4 5 6 7

3. expression demanded –
   Expression produced –
   Rate the expression produced on a scale of 1 to 7
   1 2 3 4 5 6 7

4. Expression demanded –
   Expression produced –
   Rate the expression produced on a scale of 1 to 7
   1 2 3 4 5 6 7

5. Expression demanded –
   Expression produced –
   Rate the expression produced on a scale of 1 to 7

   1 2 3 4 5 6 7

6. Expression demanded –
   Expression produced –
   Rate the expression produced on a scale of 1 to 7
   1 2 3 4 5 6 7

Other facial movement demanded: Please label the facial movement demanded and then rate

1. Facial movement demanded –
   Facial movement produced – Yes/No

2. Facial movement demanded –
   Facial movement produced – Yes/ No

3. Facial movement demanded –
   Facial movement produced – Yes / No

PART 2

Facial expression in story compression condition: Please label the spontaneous and explicit facial expression produced and the expression label provided by children

1. Any spontaneous facial expression produced – yes/no
   Label spontaneous facial expression –
   happy sad fear anger disgust surprise

   Expression label provided by the child –
   Correct label – Happy

If correct then rate the explicit expression on a scale of 1 to 7

1 2 3 4 5 6 7

2. Any spontaneous facial expression produced – yes/no

   Label spontaneous facial expression –

   happy sad fear anger disgust surprise

   Expression label provided by the child –

   Correct label – Angry

   If correct then rate the explicit expression on a scale of 1 to 7

   1 2 3 4 5 6 7

3. Any spontaneous facial expression produced – yes/no

   Label spontaneous facial expression –

   Happy sad fear anger disgust surprise

   Expression label provided by the child –

   Correct label – disgust

   If correct then rate the explicit expression on a scale of 1 to 7

   1 2 3 4 5 6 7

4. Any spontaneous facial expression produced – yes/no

   Label spontaneous facial expression –

   happy sad fear anger disgust surprise

   Expression label provided by the child –

   Correct label – Fear

   If correct then rate the explicit expression on a scale of 1 to 7

   1 2 3 4 5 6 7

5. Any spontaneous facial expression produced – yes/no

   Label spontaneous facial expression –

   happy sad fear anger disgust surprise

Expression label provided by the child –

Correct label – Happy

If correct then rate the explicit expression on a scale of 1 to 7

1 2 3 4 5 6 7

6. Any spontaneous facial expression produced – yes/no

   Label spontaneous facial expression –

   happy sad fear anger disgust surprise

   Expression label provided by the child –

   Correct label – Surprise

   If correct then rate the explicit expression on a scale of 1 to 7

   1 2 3 4 5 6 7

7. Any spontaneous facial expression produced – yes/no

   Label spontaneous facial expression –

   happy sad fear anger disgust surprise

   Expression label provided by the child –

   Correct label – Sad

   If correct then rate the explicit expression on a scale of 1 to 7

   1 2 3 4 5 6 7

8. Any spontaneous facial expression produced – yes/no

   Label spontaneous facial expression –

   happy sad fear anger disgust surprise

   Expression label provided by the child –

   Correct label – Angry

   If correct then rate the explicit expression on a scale of 1 to 7

   1 2 3 4 5 6 7

9. Any spontaneous facial expression produced – yes/no

   Label spontaneous facial expression –

happy sad fear anger disgust surprise

Expression label provided by the child –

Correct label – Disgust

If correct then rate the explicit expression on a scale of 1 to 7

1 2 3 4 5 6 7

10. Any spontaneous facial expression produced – yes/no

Label spontaneous facial expression –

happy sad fear anger disgust surprise

Expression label provided by the child –

Correct label – Fear

If correct then rate the explicit expression on a scale of 1 to 7

1 2 3 4 5 6 7

11. Any spontaneous facial expression produced – yes/no

Label spontaneous facial expression –

happy sad fear anger disgust surprise

Expression label provided by the child –

Correct label – Surprise

If correct then rate the explicit expression on a scale of 1 to 7

1 2 3 4 5 6 7

12. Any spontaneous facial expression produced – yes/no

Label spontaneous facial expression –

happy sad fear anger disgust surprise

Expression label provided by the child –

Correct label – Sad

If correct then rate the explicit expression on a scale of 1 to 7

1 2 3 4 5 6 7

Appendix 5

Age and IQ of HFA and MC participants for inner outer research

Participant	FSIQ	VIQ	PIQ	Age
HFA	85	89	84	11.2
HFA	89	97	85	14.9
HFA	91	95	90	11.5
HFA	93	86	103	14.7
HFA	97	86	109	15
HFA	98	103	93	12.1
HFA	101	102	99	15
HFA	104	103	103	13.3
HFA	104	98	108	13.2
HFA	105	96	114	11.2
HFA	108	125	91	13.7
HFA	114	115	109	10.5
HFA	116	121	106	15.5
HFA	117	108	124	13.10
HFA	118	118	115	12.7
HFA	129	135	117	12.1
HFA	132	127	129	13.3
MC	84	85	86	11.10
MC	98	94	101	14.6
MC	89	106	77	11.6
MC	95	87	104	14.5
MC	94	87	103	15
MC	97	98	95	12.8
MC	103	89	117	14.4
MC	105	95	113	12.6
MC	105	106	103	13.6
MC	111	108	111	11.4
MC	109	105	114	12.3
MC	113	114	110	10.5
MC	112	113	108	15
MC	117	118	111	13.2
MC	120	109	128	12
MC	124	139	104	12.7
MC	128	131	119	13.4

Appendix 6

Table .1 Correlation between FR scores and IQ for HFA and MC

	HFA Pearson's r	P value	MC Pearson's r	P value
Full to inner face and IQ	0.259	0.315	0.258	0.317
Inner to full face and IQ	-0.22	0.397	0.15	0.565
Inner to inner face and IQ	0.406	0.105	0.404	0.108

Table .2 Correlations between FE on demand scores and IQ for HFA and MC

On demand	HFA Pearson's r	P value	MC Pearson's r	P value
Happy	0.1	0.657	0.176	0.433
Sad	-0.17	0.426	0.117	0.605
Angry	0.301	0.174	-0.144	0.522
surprise	0.356	0.104	-0.507	0.801
Fear	0.094	0.677	0.067	0.768
Disgust	-0.053	0.815	-0.097	0.667

Table .3 Correlation between FE with context scores and IQ for HFA and MC

With context	HFA Pearson's r	P value	MC Pearson's r	P value
Happy	0.106	0.639	0.114	0.613
Sad	-0.402	0.064	0.069	0.759
Angry	0.097	0.667	0.121	0.591
Surprise	-0.158	0.481	-0.077	0.735
Fear	0.015	0.948	0.046	0.839
Disgust	-0.06	0.791	0.164	0.465

Table .4 Correlation between story label scores and IQ for HFA and MC

Story labels	HFA Pearson's r	P value	MC Pearson's r	P value
Happy	0.245	0.271	-0.404	0.062
Sad	-0.035	0.878	0.02	0.931
Angry	0.012	0.958	0.182	0.418
Surprise	-0.222	0.321	0.248	0.265
Fear	-0.431	0.045*	0.297	0.18
Disgust	0.24	0.282	0.057	0.801

Chapter 13

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