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EMOTION PROCESSING AND SOCIAL COGNITION IN DEAF CHILDREN

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ABSTRACT

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EMOTION PROCESSING AND SOCIAL COGNITION IN DEAF CHILDREN

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Understanding others' emotions and false beliefs, known as Theory of Mind (ToM), and to recognise and produce facial expressions of emotion has been linked to social competence. Deaf children born to hearing parents have commonly shown a deficit, or at best a delay in ToM. The emotion processing skills of deaf children are less clear. The main aims of this thesis were to clarify the ability of emotion recognition in deaf children, and to provide the first investigation in emotion production.

While deaf children were poorer than hearing controls at recognising expressions of emotion in cartoon faces, a similar pattern was found in both groups' recognition of real human faces of the six basic emotions (happiness, sadness, anger, fear, disgust and surprise). For deaf children, emotion recognition was better in dynamic rather than static, and intense rather than subtle, displays of emotion. With the exception of disgust, no differences in individual emotions were found, suggesting that the use of ecologically valid dynamic real faces facilitates deaf children's emotion recognition.

Deaf children's ability to produce the six basic emotions was compared to hearing children by videoing voluntary encodings of facial expression elicited via verbal labels and emotion signed stories, and the imitation of dynamic displays of real facial expressions of emotion. With the exception of a poorer performance in imitation and the verbally elicited production of disgust, deaf children were consistently rated by human judges overall as producing more recognisable and intense expressions, suggesting that clarity and expressiveness may be important to deaf individuals' emotion display rules.

In line with previous studies, results showed a delay in passing the first and second order belief tasks in comparison to age matched controls, but not in comparison to a group of 'age appropriate' hearing control children. These findings encouragingly suggest that while deaf children of hearing parents show a delay in ToM and understanding disgust, emotion processing skills follow a broadly similar pattern of development to hearing control children. Language experience is implicated in difficulties faced in social and emotion cognition, with reduced opportunities to discuss more complex emotional and mental states.

Key words: Emotion recognition, emotion production, Theory of Mind, deafness

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ADFES	Amsterdam Dynamic Facial Expression Set
ANOVA	Analysis of Variance
ASD	Autism Spectrum Disorder
ASL	American Sign Language
AU	Action Unit
BPVS	British Picture Vocabulary Scale
BSL	British Sign Language
CA	Chronological Age
CI	Cochlear Implant
CODA	Child of Deaf Adult
CPM	Colour Progressive Matrices
EIT	Emotion Identification Test
FACS	Facial Action Coding System
HA	Hearing Aid
IQ	Intelligence Quotient
PPVT	Peabody Picture Vocabulary Test
SD	Standard Deviation
SSE	Sign Supported English
ToM	Theory of Mind

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Chapter One: Introduction

Emotional competency can be identified by the optimal functioning of the 'emotion mechanism' in two key domains – emotion production and emotion perception (or recognition) (Scherer, 2007). Proficiency in emotion production refers to the appropriateness of facial and bodily changes in response to an event, whereas proficiency in emotion perception refers to the skill of accurately recognising and interpreting emotional states of others in social interactions (Bänziger, Grandjean & Scherer, 2009). The studies in this thesis aim to investigate emotion competency and understanding in deaf children through these two key aspects of emotion processing.

Children with severe or profound deafness born to hearing parents have been shown to display delays in their development of some social cognitive abilities. It is thought that the relative paucity of exposure to emotional and mental state language is due to lack of access to overhearing conversations of others (Marschark, 1993). There is substantial evidence indicating that deaf children, in particular, late-signing or oral deaf children, have at the very best a delay, or a deficit in theory of mind (ToM) (i.e. understanding of other's beliefs, intentions and actions; Peterson & Siegal, 1995). Less clear is the exact reasons for these delays and whether they extend to and include difficulties in understanding and recognising others' emotions (Dyck, Farrugia, Shochet & Holmes-Brown, 2004). This ability is an important consideration because being unable to gauge the emotional state of another may lead to a lack of awareness of the individual's impact on others, a lack of empathy and inappropriate social skills (Mellon, 2000). It is hoped that by extending the study of emotion processing to include emotion recognition, emotion production and ToM ability, it will inform our understanding of atypical emotion development in a deaf population. This may provide important clues not only as to whether children show a delay, a deficit or even an intact understanding of emotions, but it may also be revealing in terms of the processes involved in their emotional development.

Deafness

Each year approximately 840 children in the UK are born with moderate to profound deafness (Royal National Institute for the Deaf, 2006; Meristo, Hjelmquist & Morgan, 2012a). The medical condition of deafness focuses on the severity of hearing loss, measured by the unaided hearing threshold in puretone decibel (dB) for the noise in the better ear. More than half of childhood deafness is genetically determined. Other causes include pre-natal complications such as rubella, and post-natal causes such as premature birth, lack of oxygen during birth or meningitis. The result of this is that up to 40% of deaf children have additional or complex needs (Action on Hearing Loss, 2011). The deaf children participating in the current thesis had no additional needs other than deafness; they had either moderate (40 -69 dB) to severe (70 – 94 dB) or profound (≥95 dB) hearing loss, meaning all children would at least have difficulty following speech without hearing aids. While deafness can be acquired later in child or adulthood, the children involved in the studies of this thesis were pre-lingually deaf, being either born deaf or acquiring deafness before spoken language acquisition.

Deaf children's methods of communication

What determines a child's preference of communication mode (sign language, oral communication) is heavily dependent upon both the deaf child's family and their local school provision (Meristo et al., 2012a). For example, the vast majority (over 90%) of deaf children are born to hearing parents. Only a minority of children grow up as ‘native signers’, who share a common language with their caregivers involving naturally adapted sign language (van Gent, Goedhart, Knoors & Treffers, 2012). The official language of the Deaf community in the UK is British Sign Language (BSL). It is in every sense just as much a human language as English or French, however, it is visuo-spatially organised, using movements of the hands, face, head and body rather than using speech (Sutton-Spence & Woll, 1999): its articulators are visual rather than oral. It has vocabulary, grammar and syntax, fully-functional, yet distinct from English. BSL is able to express complex concepts and ideas like any other language. Many of the signs are arbitrary in their meaning, making it incomprehensible to an English person, or someone who communicates in another sign language, such as American Sign Language (ASL).

Since the majority of deaf children grow up in hearing families and attend mainstream schools (approximately 85 %; National Deaf Children’s Society, 2010), BSL is not often the primary method of communication that is adopted. An oral deaf person is defined by those who live in the hearing world by reading lips and learning how to speak. With hearing amplification – increasingly, the use of cochlear implants (CIs) – oral deaf children rely on lip-reading in addition to residual hearing to communicate in a hearing environment; in some school settings, with the use of only English (Lachs, Pisoni, & Kirk, 2001). To accompany this, many deaf children additionally learn some form of sign language: most commonly, Sign Supported English (SSE). Using some BSL signs alongside spoken English, SSE follows English word order as well as using additional sign markers to show English grammar (e.g. prepositions such as ‘with’) (Sutton-Spence & Woll, 1999). It is considered straightforward for English users to learn.

While BSL is a fully developed, natural language, manual encodings of spoken language (such as SSE) are not, but they are often used in providing simultaneous translation and in communication with hearing signers. As highly qualified human hearing signers are a scarce and undervalued resource, it has been shown that deaf children tend to experience communication along a continuum of 'dialects', ranging from SSE to BSL (Pezeshkpour, Marshall, Elliott, & Bangham, 1999). Among these children, oral and late signing deaf children who know little sign may be at a disadvantage compared to those more experienced signers, as communication with others is often poorer in content. Even when a family learns to sign with their deaf child, it is rare that fluency is reached and signed communication is limited to interacting directly with the child. Therefore, for many, due to this reduced opportunity for everyday conversation, deafness may have an impact not only on spoken language development, but also educational achievement and social-emotional development (Marschark, 2007).

Cochlear Implementation: increased language access?

A fairly recent and notable development affecting the deaf community is the increased use of neonatal screening for deafness (Young & Tattersall, 2007); severe and profoundly deaf children of hearing parents are increasingly more likely to receive CIs at younger ages (Spencer & Marschark, 2003), potentially altering the prognosis of development. A CI is an electronic device surgically implanted in the cochlea, which directly stimulates the auditory nerve, enabling sensitivity to sound for even profoundly deaf individuals (Remmel & Peters, 2008). CIs, however, do not result in natural hearing and have sparked a debate of controversy. Caution is drawn to interpreting cochlear implementation as a 'cure' for deafness (National Association of the Deaf, 2000). Auditory information is coarse, extensive speech and language therapy is required and outcomes have been variable and not effective for all deaf children (Christiansen & Leigh, 2002; Bat-Chava & Deignan, 2001).

A number of factors have been implicated in the variability of outcomes such as: duration of cochlear implantation; age at implantation; residual hearing before implantation; technical, physiological and technological factors, and children's cognitive skills (Schorr, Fox, van Wassenhove & Knudsen, 2005). Yet in general, much literature has shown that cochlear implantation seems to accelerate spoken language acquisition (Geers, 2006) and these devices have been shown to be effective in improving deaf children's perception of speech (Lee, Charles, & Michael, 2010; Sharma, Dorman, & Spahr, 2002). Potentially greater access to the hearing world may additionally result in improvements in deaf children's socio-emotional development (Tasker, Nowakowski & Schmidt, 2010), but this is yet to be firmly established.

The social impacts of deafness

The overwhelming focus on the implications of deafness has understandably centred on its impact on hearing, language acquisition and speech development. Much less consideration has been given to what Marschark (1993) refers to as the "secondary effects" of deafness, namely the resultant effects on social, emotional and cognitive functioning. The basis of the development of these functions is dependent on a child's interaction with their environment. As such, if a child is born to parents who are skilled in non-verbal communication – typically, those deaf children born to deaf signing parents, it is possible that little or no impact of deafness on the mother-infant interactions and early interactions may be found. Yet, while there is increased awareness of sign language (Morgan & Woll, 2002), the majority of deaf children are born to hearing parents who have no previous knowledge of sign language and little understanding of how to adapt their spoken language to make communication more accessible for their infant in the first few years of life (Mitchell & Karchmer, 2004).

Children's early interaction with others has been shown to be crucial to acquiring the necessary social skills, including the ability to take multiple perspectives, and to initiate and sustain friendships (Anita & Kreimeyer, 2003). Deaf children of hearing parents in mainstream schools have been shown to have poorer ratings of social competence as measured by lower ratings of pro-social behaviour and higher levels of socially withdrawn behaviour in comparison to hearing children (Wauters & Knoors, 2008). Although not disliked by hearing peers, deaf children have been shown to be likely to have fewer friends and experience isolation in mainstream schools in the UK (Nunes, Pretzlik & Olsson, 2001).

A study with Israeli deaf children revealed that speech intelligibility of deaf children has been shown to strongly correlate with a perceived sense of loneliness, suggesting that poorer language abilities impedes building social connections (Most, Ingber & Heled-Ariam, 2012). In a small-scale observational study examining the performance of deaf children with CIs on a Peer Entry task[1], better outcomes were revealed in one-on-one situations in comparison with interactions with two or more others (Martin, Bat-Chava, Lalwani & Waltzman, 2011). This suggests that social situations are more challenging for deaf children due to difficulty in tapping into multiple simultaneous conversations, which clearly includes conversations revolving around emotions and mental states. Research specifically documenting deaf children's social skills is relatively sparse and is heavily reliant on self-report (peer

[1] Measures the ability to enter a group of peers

and teacher) measures. To date, the vast majority of research on deaf children's social functioning has focused on the social-cognitive skill of ToM.

Theory of Mind

A distinguishing characteristic of human social cognition is our inclination to look beyond external behaviour and to consider the psychological states of others. A tendency to focus on people's emotions, desires, intentions and thoughts, and to refer to these when predicting and explaining behaviour, is what constitutes Theory of Mind (ToM) (Slaughter & Peterson, 2012). This ability is important in aiding us to understand ourselves and others, and a vital basis of self-organisation and affect regulation. ToM encompasses all skills required to effectively manage social communication and relationships in humans and nonhumans (Korkmaz, 2011).

A deficit in ToM was originally associated with children with the neurological developmental disorder, autism, and this includes the high functioning autistic children with normal intelligence and other intact cognitive abilities (Frith & Frith, 2003). Yet deaf children of hearing parents (Peterson & Siegal, 1995), as well as congenitally blind children (Hobson, Lee & Brown, 1999) and children with cerebral palsy (Dahlgren, Dahlgren Sandberg & Hjelmquist, 2003), are other groups of atypically developing children demonstrating similar ToM difficulties, suggesting a neurobiological explanation does not alone account for such problems in understanding others' mental states. In the absence of a cognitive deficit resulting in impaired social interaction, deaf children of hearing parents instead are disadvantaged in terms of opportunities to communicate in everyday situations.

How is Theory of Mind measured?

This ability is typically measured by enacting a social scenario and questioning a child on the thoughts and actions of the protagonist, commonly presented in a story with the use of pictures or acted out with puppets. The litmus test of ToM – the 'false-belief' task – relies on the assumption that people can have beliefs about the world that are inaccurate (Wimmer & Perner, 1983). In essence, passing the task requires an understanding that the character in question will have a false belief due to being unaware of a crucial *'change-in-location'* (e.g. the 'Maxi task' or the 'Sally Anne' task of Baron-Cohen, Leslie & Frith,1985), or a contradiction in *'appearance'* and '*reality'* (e.g. Smarties task: Perner, Leekam & Wimmer, 1987). Where many 3-year-old children tend to fail measures of ToM reasoning, typically developing 4- and 5-year-old children reliably pass such tests with ease (Wellman, Cross & Watson, 2001). By 7-years old, children have typically extended their understanding to appreciate multiple perspectives (Selman, 1980). A 'second-order' false belief task requires the attribution of a first-order belief (Person A thinks X) to another person (Person B thinks "Person A thinks X") (Baron-Cohen, 1989).

A broader concept of Theory of Mind

The paradoxical contrast between the readily apparent social skills of children under the age of three and a failure to pass the false belief tasks has called into question the usefulness of defining ToM purely based upon success on the false belief task (Ashington, 2001). Consequentially, a number of researchers have sought to broaden this definition to encompass a wider range of mental states including perception, intention, cognition and emotion (Hughes & Leekam, 2004). For instance, Tager-Flusberg and Sullivan (2000) proposed a two part model of ToM that can be separated into *social-cognitive* and *social-perceptual* components of ToM, and together they constitute 'social knowledge.' The *social-cognitive* component entails a representational understanding of the mind (most commonly signified by passing the false belief task), which emerges alongside other cognitive abilities, including working memory and general and specific language abilities (Tager-Flusberg & Sullivan, 2000).

Tager-Flusberg and Sullivan (2000) term the second component, *social-perceptual* ToM, as it is more closely related to the affective system: the 'rubric of person perception', including the ability to rapidly make an implicit judgement of a person's mental state via facial and bodily expressions. There is evidence that the social-perceptual component begins to emerge at an earlier stage of development; for example, new born infants have been shown to attend to social stimuli within the first few weeks of life (Mehler & Dupoux, 1994).

There is debate surrounding the relationship between the *social-perceptual* skills emerging from infancy, such as joint visual attention, social referencing, imitation, communicative vocalisations and gestures, and the later emerging *social-cognitive* ToM (Hughes & Leekam, 2004). A number of theorists have argued that the *social-perceptual* component of ToM is an essential building block for the later emergence of *social-cognitive* ToM (Baron-Cohen, 1997; Frith & Frith, 2003; Hobson, 1993). This nativist perspective suggests that a child's social environment can trigger but not essentially determine ToM development, which instead occurs as a maturational progress with universal developmental milestones (Frith & Frith, 2003). Thus a faulty mentalising capacity is associated in children with autism (Baron-Cohen, 1997; Leslie, 1994). For instance, Hobson (1991) proposed an association between primitive forms of relatedness – ‘affectively charged interpersonal relations’ - and ToM. Hobson argued that being able to differentiate between the self and others occurs via the innately determined ability of affect perception, i.e. the ability to perceive affect in the behaviour and bodily appearances of others.

Alternatively, other accounts place a greater emphasis on the process of socialisation: a notable account that takes environmental experience into consideration is ‘simulation theory’ (Harris, 1991). According to simulation theory, acquisition of ToM is dependent upon a child’s capacity for pretence so to be able to imagine another person’s position in a hypothetical scenario (Hughes & Leekam, 2004; Kormaz, 2011). This theoretical standpoint indicates that differences in children’s social environment with varying levels of opportunity to engage in pretend play impacts on ToM development. Indeed, in a longitudinal study, McAlister and Peterson (2007) found that number of siblings predicted performance on formal tests of ToM.

Theory of Mind in deaf children: performance on false belief tasks

The widely documented difficulty in ToM found in congenitally deaf children of hearing parents offers an insight into the role social interaction skills may play in ToM development. Contrasting performance between native and late-signing deaf children on the false belief task provides a strong indication that language experiences mediate ToM development. The great majority of deaf children are born to hearing parents, and these children show delays in false belief understanding. In contrast, native signing deaf children show comparable performance to hearing children (Courtin & Melot, 1998; de Villiers & de Villiers, 2000; Figueras, Cost &

Harris, 2001; Peterson & Siegal, 1995, 1997, 1998, 2000; Schick, De Villiers, De Villiers & Hoffmeister, 2007).

Peterson and Siegal (1995, 1997, 1998) first demonstrated that deaf children age 8-13 years were failing the false belief task in comparison to 5 year old hearing children and showed comparable performance to autistic children. In an attempt to overcome the potential language barrier because of the highly verbal nature of the false belief task, Woolfe, Want and Siegal (2002) presented the false belief task in non-verbal task in a series of 'thought pictures' to deaf children between 4 and 8 years old. The late-signing deaf children were still shown to display a deficit in false belief understanding, even when controlling for executive functioning, syntax and non-verbal ability.

However, not all studies investigating false belief understanding in deaf children have indicated such poor performance. Schick et al. (2007) found that while oral and late-signing deaf children's overall performance was poorer than that of native signers and hearing children, by age 7 the oral children's performance on the low verbal false belief tasks was equivalent to the comparison group's and the late-signing deaf children were comparable on both the low verbal *and* verbal false belief tasks. A key difference is that Schick was a native signer, whereas many other studies investigating deaf children's false belief tasks have relied upon an interpreter, which adds an additional demand on children's attention as switching back and forth between the interpreter and experimenter is required (e.g. Peterson & Siegal, 1995, 1999; Peterson, 2002, 2004, 2009; Peterson & Slaughter, 2006).

Studies investigating false belief understanding among deaf children with CIs have also revealed inconsistent findings. Peterson (2004) found that deaf children with CIs were delayed in ToM acquisition by 3 to 5 years, whereas Peters and colleagues found that children aged 3 – 12 years revealed only marginal delays (Peters, Remmel & Richards, 2009; Remmel & Peters, 2008). These studies showed that some children with CIs paralleled hearing children in false belief performance and positive correlations were found with duration of implantation and task performance. More recently, Ziv, Most and Cohen (2013) found that false belief task performance of younger deaf Israeli children with CIs aged 5- 7 was also higher than previous studies with deaf oral children without cochlear implants. However, Ziv et al. (2013) highlighted that caution needs to be applied in interpreting these results due to great variance within the group of CI wearers, a number of whom showed poorer performance and low verbal ability.

Experience with language is clearly implicated in the development of mentalising abilities in deaf children of hearing parents. It has been highlighted that those children with fluent sign language, most notably native signing deaf children, will have experienced the grammatical framework of formalised sign language that contains the necessary structure to communicate point-of-view and visual perspective (Courtin, 2000). In contrast, the late-signing and oral deaf children have limited or no skills in sign and so lack a common language, leading to a reduced opportunity to overhear conversations and a reduced faculty to converse about mental states (Vaccari & Marschark, 1997). One prominent view is that understanding of mental states evolves out of conversational exchanges with others (Peterson et al., 2000; Woolfe et al., 2002). Moeller and Schick's (2006) study provided evidence for a link between mother's mental state talk and deaf children's ToM, and Woolfe et al. (2003) found that number of siblings was a positive predictor of false belief performance. Vocabulary and understanding syntactic complements have been shown to be significant predictors of ToM performance (De Villiers & De Villiers, 2000; Schick et al., 2007), yet the exact role of language remains unclear.

Beyond false belief: deaf children's non-verbal communication with others

Some researchers have criticised solely focussing on the false belief task as a measure of ToM. For example, Bloom and German (2000) highlighted that besides simply passing a false belief task, ToM ability encompasses a wide range of abilities such as deception and pretend play. While research with children with perceptual impairments draws particular attention to the importance of communication experiences for a representational ToM, it is difficult to precisely determine which element or multiple elements contribute to false belief understanding (Hughes & Leekam, 2004). One of the strongest arguments is that failure on false belief task is attributable to a lag in the mastery of the syntax of sentential complements (De Villiers & De Villiers, 2000; Schick et al., 2007). Yet this argument faces difficulties upon the consideration that deaf children have performed worse than hearing controls in pre-verbal belief attribution tasks. For instance, in a non-verbal looking study, Meristo, et al. (2012b) found that hearing infants outperformed deaf infants in anticipating a character's false belief by tracking their gaze to the search location.

The view that early conversational experiences lead to a grasp of mental state concepts could explain this outcome, particularly given the recent finding that hearing mothers of hearing children use significantly more references to mental states when talking to their infants than hearing mothers of deaf infants (Morgan, Meristo, Mann, Hjelmquist, Surian & Siegal, 2014). Meristo et al. (2012b) reasoned that the relatively impoverished early communication between deaf infants and hearing parents impacts on preverbal deaf infants' early visual attention, which mirrors later delays on social-cognitive ToM tests. What is not precisely clear is whether it is conversation itself that is the crucial linguistic mediator or whether non-verbal interactions play an important role (Hughes & Leekham, 2004).

Careful consideration needs to be given to the early social-perceptual skills of deaf children that may contribute to later difficulties in ToM. One important early social interaction for an infant is joint attention. Joint attention skills involve sharing attention with a caregiver through pointing, showing and coordinating looks between objects of interest and people (Tomasello, 1995). The interaction between deaf infants with deaf parents appears to take a different developmental pathway to deaf infants with hearing parents (Koester, Papousek & Smith-Gray, 2000; Prezbindowski, Adamson and Lederberg, 1998). Deaf infants from deaf families have been shown to have skilful abilities in shifting attention or gaze between objects, the environment and their parents, creating sequences of shared, symbolic and linguistic meaning in comparison to deaf infants with hearing mothers (Koester et al., 2000; Loots, Devise & Jacquet, 2005). Koester and colleagues found that strategies employed by deaf parents include the use of exaggerated facial expressions of emotion and greater use of physical contact. On the other hand, hearing-mothers of deaf infants engage in a sequence involving shifting visual attention between the environment and their communication partner, thus restricting the co-ordinated joint attention that hearing children perform in a visual-auditory way. It is noteworthy, however, that there is individual variation within the population of hearing mothers of deaf infants, and some mothers have shown effective compensatory strategies for the lack of auditory input (Tasker et al., 2010; Traci & Koester, 2003).

It is possible that differences in deaf children's early experiences of inter-subjectivity may lead later delays in passing the false belief task. Interestingly, in a longitudinal study, symbolic joint attention was shown to later predict preschoolers' ToM (Nelson, Adamson & Bakeman, 2008). While it may seem logical that non-verbal behaviour in the visual domain could be preserved and even optimised in deaf children, research has highlighted that the majority of hearing parents are not sufficiently proficient in sign language and gestural communication to initiate and sustain social interactions and conversation revolving around others' beliefs (Spencer & Harris, 2006; Vaccari & Marschark, 1997). With an absence of the pragmatic context of verbal and gestural communication, it is far harder for deaf children to grasp mental state and language referring to others' emotions (Meristo et al., 2012).

There is a clear rationale to consider broader aspects of ToM, as illustrated by examples of differences in joint attention and implicit ToM as measured by direction of gaze. Studies with blind children who are delayed (but later they parallel sighted peers) in word acquisition (e.g. Landau & Gleitman, 1985), draws attention to the likelihood that non-verbal cues (e.g. joint attention and emotion perception) play an important role in language acquisition given that blind children are lacking access to these signals. Thus for deaf children, too, these early non-verbal skills may be pivotal to early conversational experience and understanding mental states. One area of research that has far less comprehensive attention is that of deaf children's non-verbal abilities in emotion perception and production.

Emotion processing

A crucial element of social interaction that is worthy of a greater focus of research attention is emotion (Hughes & Leekam, 2008). Perceiving and interpreting other people's emotional states is critical for effective social communication (Atkinson & Adolphs, 2005; Bänziger et al., 2009). The ability to effectively produce emotions has received less consideration but is also of importance as children who are able to better communicate their feelings have been shown to display better social skills and interactions (Boyatzis & Satyaprasad, 1994). There is a link between mind and emotion in making sense of people's actions in everyday situations. For instance, an individual's emotional reaction (such as happiness or surprise) is connected to and moulded by various mental states (such as the other person's desires or beliefs) (Wellman & Banerjee, 1991).

What are emotions and what is their function?

A lack of consistency in determining differences between explicit and implicit definitions of emotion has dominated this field of research. There is, however, a general consensus that emotions have motivational and regulatory functions and can be separated into basic emotions, which manifest in infancy and early childhood, and later emerging more complex emotions, often involving higher-order cognition (Izard, 2007). Izard (2007) defines a basic emotion as a set of neural, bodily/expressive, and feeling/motivational components. The basic emotions are produced rapidly and spontaneously without consciousness when the perception of an ecologically valid stimulus occurs.

The origin and function of emotions is hotly debated. Russell and colleagues (Widen & Russell, 2003, 2008a) argue that emotion is to be understood on a continuous dimension in the brain measured in terms of valence (positive/pleasurable vs. negative/displeasurable) and arousal in response to stimuli. In contrast, others maintain that emotions fall into discrete categories that are innate (even though not initially verbalised or labelled) and produce an explicit prototypical response; this includes an emotion specific pattern of facial expression (Ekman, 1992; Izard, 2007, 2009). For discreet emotion theorists, there is a general consensus that there are six universal basic emotions – happiness, sadness, anger, fear, disgust and surprise –that emerged in early ontogeny determined from evolutionary adapted neurobiological systems (Ekman, 1994, 1999; Izard, 1971, 2007). Barrett contests that these 'psychological phenomena' or 'events' (i.e. happiness, sadness etc.) are not posed in this stereotypical fashion in everyday life, proposing that language provides a context to reduce the ambiguity of this information (Barrett, Lindquist & Gendron, 2007). Rather, Barrett at al. (2007) argue that these events are constructed from at least two basic psychological processes: a primitive, biologically based system called 'core affect' that varies on the basis of positive or negative states, and a human conceptual system for emotion (i.e. knowledge about emotion), which includes a role for language.

Other research on emotions has focused on their inherent social function, arguing this is paramount given that emotions are elicited and evolve within social contexts (Fischer & Manstead, 2008). Fischer and Manstead (2008) posit that emotions have two important social functions: that of distancing the self from another, and affiliating the self with another. The appropriateness of a particular reaction will, however, vary from social context to social context, between cultures, and be somewhat dependent on social appraisal[2]. The function of sadness for example, is to gain support and consolation from others, yet crying in certain public situations may result in the individual being ridiculed. The processes of mimicry and

[2] Social appraisal refers to an individual's belief about a particular event (Widen & Russell, 2008a)

emotional contagion, for example, can be interpreted as having an affiliative function in social relations. Fischer and Manstead (2008) explain that mimicry refers to the automatic processing of others' nonverbal displays, causing an individual to produce similar non-verbal displays. Emotion contagion, on the other hand, explains the tendency of others' emotions to influence an emotional experience. Indeed, both have been shown to increase when an individual feels able to identify with, or show empathy towards, another person (Fischer, Rotteveel, Evers & Manstead, 2004; Sonnby-Borgström, 2002).

Importance of socialisation in developing emotion understanding in deaf children

As the expression of emotion is a social signal, an important aspect of social development is the understanding of emotions felt by the individual, as well as those expressed by others. Given the theoretical viewpoint that suggests that emotion signals are understood as a process of socialisation and develop in parallel with language, deaf children's reduced opportunities for social experience may mediate their development of skills in non-verbal emotion perception.

To understand another person's emotion perspective an individual is required to be able to imagine how that person may feel without directly experiencing or sharing that person's perspective (Harris, 1991). Crucial to the process of emotion understanding are interpreting facial and vocal expressions of emotion as well as a comprehension of situations that are likely to elicit a given emotion reaction (Saarni, Mumme & Campos, 1998). Denham and Dunn have stressed the role that parents take in the development of a young child's emotion understanding (Denham, Mitchell-Copeland, Strandberg, Auerbach & Blair, 1997). The reciprocity of the parent-child relationship in infancy, including interactive strategies such as joint attention and infant directed speech, familiarises the child with social messages with emotional content (Dunn, Brown & Beardsall, 1991). Peers are also important in social and emotional development as pretend play provides a context for children to socialise and use mental state talk (Brown, Donelan-McCall & Dunn, 1996).

Harris (1989) presents a framework of emotion understanding that explains the development from the first interactive states with caregivers during infancy, to the practice and refinement of these routines with peers at school, to the later emergence of the cognitive ability to take the emotion perspective of another person, known as 'imaginative understanding.' As a typical child proceeds through childhood there are increasing opportunities for emotional learning of greater complexity by conversing about emotions and emotional experiences with others.

The generally held view is that deaf children of hearing parents encounter a barrier to engaging in social interaction, resulting in fewer opportunities to learn about emotion and emotional experiences. There is evidence to suggest that children with pre-lingual deafness with hearing parents consequences in less frequent and shorter conversational parent-child interactions (Gray, Hosie, Russell, Scott & Hunter, 2007; Lederberg & Everhert, 1998; Lederberg & Mobley, 1990; Wedell-Monnig & Lumley, 1980). Meadow (1976) found that communication between deaf children and their hearing parents was limited to concrete situations with an available visual referent. It is therefore not surprising that this limited conversation does not extend to emotion experience and that hearing parents with deaf infants use fewer mental state terms (Morgan et al., 2014).

It has also been shown that parents and caregivers of deaf children are less likely to give justifications of their emotions (Gregory, 1976). Deaf children have been shown to spend less time in cooperative play (Higginbotham & Baker, 1981;

Vandell & George, 1981) and are less likely to initiate play interactions than hearing children, and as a result, this makes it more difficult to practise play based skills, in particular pretend play (Anita & Kreimeyer, 2003). In addition to a reduction in opportunities to engage in these types of interactions that results in natural, spontaneous discussion of emotion, deaf children in hearing environments cannot overhear other conversations unless they are directly involved (Gray et al., 2007).

Deaf children's abilities in emotion recognition and production may be revealing in terms of how emotion understanding develops. If emotion does originate from a genetically evolved response system organised into discrete emotion categories, deaf children should demonstrate no differences. Conversely, differences in deaf children's emotion processing may indicate the importance of interaction with the environment in understanding and displaying emotion facial configurations. Indeed, even if emotion perception occurs unconsciously it may be that emotionally and socially relevant conceptual knowledge is able to effectively shape perception either with or without awareness, meaning that visual processing is not in itself sufficient (Atkinson & Adolphs, 2005).

Facial emotion recognition in typically developing children

One of the key areas of a young child's emotional development is the ability of emotion recognition: that is, to be able to accurately process and decode emotional information produced by the self and others (McClure, 2000). On the basis of the universality argument (Ekman, 1972; Izard, 1971), the study of facial expressions has been dominant in assessing emotion recognition abilities. Being able to rapidly recognise facial expressions of emotion with accuracy is thought to be vital for successful social interaction and to appropriately respond to another person's signal

(Herba & Phillips, 2004). A deficit in emotion facial recognition has been linked to impairments in social functioning and has been shown to be a potential risk factor for psychopathy in adulthood (Green, Kern, Robertson, Sergi & Kee, 2000).The face is believed to be the most important channel of emotion expression in humans (Mehrabian, 1981; Lemerise & Arsenio, 2000). This is because faces, in particular the eye region, convey a multitude of cues that are crucial in enabling us to disambiguate the beliefs and intentions of others (de Gelder & Vroomen, 2000).

A number of studies using habituation/preference methodologies have illustrated that children as young as three months old are able to discriminate happy and sad faces from surprised faces (Young-Browne, Rosenfeld, & Horowitz, 1977). By six or seven months, Nelson & De Haan (1997) found that young infants were able to distinguish between faces displaying mild or intense expressions of emotion; by seven months infants are also able to discriminate between dynamic presentations of happy and angry faces (Soken & Pick, 1992).

Yet there are methodological differences that result in differences of opinion in terms of at what age children can perceive and understand emotions through an emotion recognition task. Habituation/preference tasks with infants requires attentional and perceptual abilities, while matching emotion facial expressions is more dependent on visual and spatial abilities (Herba, Landau, Russell, Ecker & Phillips, 2006). Categorisation of emotions with a verbal label is arguably more revealing in terms of emotion understanding. By the age of four years, typically developing children have been shown to be able to label prototypical facial expressions of happiness, anger and sadness and are becoming more proficient at recognising surprise (Widen & Russell, 2003). Markham and Adams (1992) emphasised that differences in performance materialise as a result of variation in experimental paradigms that differ in their dependency on cognitive, visual perspective and emotional vocabulary.

Widen and Russell’s (2003) differentiation model posits that children’s ‘errors’ in categorisation is particularly informative of children’s developing emotion understanding and draws attention to the fact that the errors made are not random. Emotion concepts are initially broad and children ‘mistakenly’ label emotions of the same valence i.e. positive emotions are usually labelled as ‘happy’ and negative emotions as ‘sad’ until children’s understanding becomes more sophisticated (Widen & Russell, 2008b). Disgust has been shown to be more problematic, even for adults (Widen & Russell, 2008c; 2013).

Although some research suggests that by aged 10 the ability to recognise emotions has reached adult levels (e.g. Durand, Gallav, Seigneuric, Robichon & Baudouin, 2007), there appears to be some variation depending on task demands. Researchers in the field of children’s emotion recognition have recently responded to the criticism that the use of posed static facial stimuli lacks ecological validity (Russell, 1994). One such example is by exploring speed of processing – between the age of 7 and 10 children have been shown to make increasingly rapid responses, in particular in response to negative emotions. A second example is the increased task demand resulting from reducing the intensity of expression - adults process emotions twice as fast as children when identifying subtle rather than intense, prototypical facial expressions of emotion (De Sonnerville et al., 2002; Gao & Maurer, 2010).

Deaf children's facial emotion recognition

There is a dearth of studies testing facially expressed emotions in individuals who are deaf. These studies have tested a broad age range of children from pre-schoolers to adolescents and have produced equivocal findings. Although some research has indicated deaf children can identify supposedly 'basic' emotions that are carried reliably by characteristic facial expressions (Hopyan-Misakyan, Gordon, Dennis & Papsin, 2009; Hosie, Gray, Russell, Scott, & Hunter, 1998; Ziv et al., 2013), other studies have indicated that deaf children make more errors than hearing children (Bachara, Raphael & Phelan, 1980; Dyck & Denver, 2003; Dyck et al., 2004; Most & Michalis, 2012; Schiff, 1973; Wiefferink, Rieffe, Ketelaar, De Raeve & Frijins, 2013).

Hosie et al. (1998) compared hearing children in two age groups (4-8 years and 8-12 years) with age-matched deaf children born to hearing parents and using a total communication method (i.e. sign and speech). Both groups had greatest difficulty in labelling some of the later developing basic emotions, in particular fear, disgust and surprise, yet the overall performance was similar between groups. Hosie concluded that these results may be an indication that there are clear and unambiguous discrete facial expressions for the six basic emotions (Izard, 1971), while also recognising that this could also mean that these deaf children may have been able to capitalise on their environmental experiences.

In contrast, Dyck, et al. (2004) tested emotion recognition of 6 – 18 year old deaf children on a facial emotion recognition task comprising morphed images of the the six basic emotions plus contempt. A deficit was found in deaf children across the age range, but this was no longer significant when language was considered as a covariate. This strongly implicates language in emotion recognition. Ludlow, Heaton, Rosset, Hills and Deruelle (2010) similarly found a deficit when comparing emotion recognition in upright and inverted faces of human and cartoon (human or non human like) faces. Deaf children demonstrated a similar processing style to hearing children as they made more errors in inverted than upright images and cartoons than human faces.

As deaf children exhibit social difficulties, Ludlow et al. (2010) proposed that the advantage for human faces found in hearing children would not exist for deaf children as they would not be dependent on the ‘social’ nature of the stimuli. This was not the case, however, and it seems that deaf children similarly rely on the clear and detailed features of real faces. The lower performance of deaf individuals when distinguishing visual emotional information could be explained by the necessity of spoken language as a context for emotion perception. When an infant views a facial expression he/she simultaneously matches the vocalization and by doing so, more readily identifies the emotion (Walker-Andrews & Lennon, 1991).

Studies comparing deaf children with different types of hearing amplification (CIs versus hearing aids (HAs) have also produced mixed findings. In a recent study, Most and Michaelis (2012) investigated emotion recognition in preschool oral deaf children (4-5 years) in comparison to hearing peers. The emotions, happiness, sadness, anger and fear were presented via neutral sentences by an actor in three modes: auditory, visual and auditory-visual combined. The results revealed that hearing children outperformed deaf children with CIs in all three modes. An earlier study with a similar methodology found that older deaf children (aged 10 to 17 years) were no different from hearing controls (Most & Aviner, 2009). However, regardless of type of hearing amplification, deaf participants, unlike the hearing controls, were no better at auditory-visual perception of emotion than the visual-only perception. Hence deaf children, in particular, those who are profoundly deaf, rely heavily on the visual mode for emotion perception.

The discrepancy between these studies is likely to be partly attributable to methodological differences. Two key differences emerge. First, deaf children demonstrate poorer performance with the use of cartoons as stimuli (Ludlow et al., 2010; Wiefferink et al., 2013) or morphed faces (Dyck et al., 2004). With a reliance on the human face in non-verbal communication (sign language and lip-reading) it may be that the face is of particular importance to deaf individuals. Second, Dyck et al. (2004) was the only study to test reaction time, which reflects an increased processing demand.

A limitation to research investigating deaf children's emotion recognition to date is the reliance on the use of static images (e.g. Hosie et al., 1998; Ludlow et al., 2010). While static images are revealing in terms of knowledge about visual emotion perception and its neural basis (Adolphs, 2002), the account of emotion perception and its neural substrates is left incomplete (Atkinson & Adolphs, 2005). Atkinson and Adolphs (2005) highlight two key shortcomings. First, static images do not take into account movements of the body and face that make important contributions to emotional and other non-verbal communication. Second, dynamic facial expressions are greater in ecological validity as there is a great deal of movement in facial expressions and bodily posture in social interactions. There is increasing evidence for a neural system, crucially including the superior temporal sulcus (STS), responsible for the perception of high-level motion stimuli, particularly face and body movements (Kilts, Egan, Gideon, Ely & Hoffman, 2003; Klesser, Doyen-Waldecker, Hofer, Hoffmann, Traue & Abler, 2011; Krumhuber & Manstead, 2013; Puce & Perrett, 2003). Motion may be of particular importance to deaf individuals given the importance motion processing has for sign language (Bosworth & Dobkins, 2002).

Emotion production

An entirely new area of research that merits investigation is that of deaf children's ability to produce or encode facial expressions of emotion. While knowing someone's emotional state is helpful as it enables reliable predictions of the other person's intentions and likely actions, there is also an implied benefit for having greater control over facial expressions – it is suggested that this allows the effective portrayal of one's own intentions towards others in everyday social contexts (Mehu, Mortillaro, Bäziger & Scherer, 2012). Ekman and Friesen (1971) claim universality in terms of when emotions are deliberately posed, suggesting that a cultural specific set of display rules emerge which prescribe situations in which emotions can be shown and to whom they can be shown. Typically developing children who are good at emotion recognition have been shown to also be able to effectively encode emotion facial expressions (Boyatzis & Satyaprasad, 1994). Children's emotion production research has also shown that positive expressions are easier to voluntarily produce (Field & Walden, 1982; Lewis, Sullivan & Vasen, 1987) and imitate (Ekman, Roper & Harper, 1980) than negative emotions, improving steadily with age.

A study testing the ability of congenitally blind children, who face similarly difficulties with social-cognitive ToM as deaf children, found that they produced significantly less accurate voluntary encodings of the six basic emotions elicited by emotion stories (Roch-Levecq, 2006). These results suggest a role for a process of socialisation: blind children's limited access to people's facial expressions and the contexts that induce them, results in restricted facial expressiveness. Similarly, deaf children have limited access to a different sensory input – that of conversation which may be critical in linking facial expressions to emotion context.

Indeed, deaf children have been shown to have difficulties in assigning labels to stories eliciting prototypical emotions (Gray et al., 2007). Display rules have also been shown to develop more slowly in deaf children of hearing parents as they have been shown to be less likely to conceal their anger for pro-social reasons (Hosie et al., 2000). These findings coupled with deaf children's potential difficulties in emotion recognition (e.g. Dyck et al., 2004; Ludlow et al., 2010) warrant exploration of deaf children's ability to accurately encode emotions.

Outline of the thesis

In the first section of this thesis, chapter two details the characteristics of the whole pool of participants and general methodology; chapters three, four and five present a series of studies aiming to clarify deaf children of hearing parents' emotion recognition abilities. Chapter three explores the effect of motion on the recognition of happiness, sadness and anger in deaf children by comparing a static with a dynamic presentation. The emotion stimuli are presented on a continuum from real human faces to human-like cartoon faces to non-human like cartoon faces, to determine whether there is a particular reliance on the real human face for deaf children. Chapter four again explores emotion recognition of static and dynamic clips of real human faces, extending to include three later developing emotions – fear, disgust and surprise. The effect of intensity (from subtle to intense expressions of emotion) and a reduced display time (500ms) is explored in chapter five.

In the second section of this thesis (chapter six), the aim is to explore a novel area of research: deaf children's emotion production abilities. The voluntary encoding of the six basic emotions is investigated via three elicitation methods: a verbal label, in the context of an emotion signed story and through the imitation of dynamic clips of real human faces. Face Reader™ software and human judgements are employed to decode the children's emotion encodings and provide ratings of intensity of expression.

In chapter seven, there is a return to the false belief paradigm to examine deaf children of hearing parents' social-cognitive ToM. A battery of tests is compiled, extended to include a second order false belief task. Chapter seven aims to address the problems placed on deaf children's attention when using an interpreter by presenting the tasks in pre-recorded clips enacted by a hearing native signer: a CODA (child of deaf adult). The final chapter will draw together all the results from these studies and provide a critical discussion, outlining the main conclusions regarding deaf children's emotion processing and social cognition, and highlighting social implications and avenues for further research.

Chapter Two

Participant characteristics and methodology

Overview

This chapter explains recruitment to the studies in this thesis and describes the characteristics of the total pool of participants. The background measures used to match deaf and hearing control participants and tests of language and communication ability are outlined. The general procedure and statistical methods employed are detailed, and issues of statistical power and ethical considerations are highlighted.

Participants

Deaf children

A total of 42 high-functioning deaf children (i.e. IQs of 70 and above) took part in the studies presented in this thesis. This group comprised 25 females and 17 males aged between 5 years 9 months and 12 years 1 month. The children were predominantly white Caucasian. These children were recruited from six primary schools, with a special unit for hearing impaired children, across the East and South East of England. A questionnaire was designed to screen whether the deaf children met the participation criteria and to gather information pertaining to deafness and communication (see Appendix A). The questionnaires were completed by a teacher of the deaf at each of the participating schools. Deaf children were recruited if they had the presence of congenital/pre-lingual hearing loss at a moderate-to-severe (>60db; N = 26) or profound level (>90db; N = 16) in their better ear. None of the deaf children had any known concomitant disorders such as autism, attention deficit disorder or cerebral palsy. Three children were excluded because their non-verbal IQ was below 70.

Participating deaf children were predominantly oral in their communication preference: 29 deaf children preferred to communicate orally and 13 preferred to communicate with sign language (BSL and/or SSE). None of the children were native signers. The majority of the oral deaf children also communicated with some SSE or BSL. Twenty-seven children had family members who had sign language skills, but the vast majority had only basic signing skills or Level 1 BSL ($N = 21$), five family members had Level 2 BSL (level required for teacher of the deaf) and one parent had Level 3 (reaching fluency). All deaf children received auditory amplification: 21 children wore Hearing Aids (HAs) and 21 children wore Cochlear Implants (CIs). Fifteen of the 21 with CIs were bilaterally implanted and the majority received their first implant late (i.e. after two years; $N = 15$).

Typically developing hearing controls

A total of 61 typically developing hearing children (35 female) took part in the studies in this thesis[3]. The hearing control group were aged between 6 years 1 month and 11 years 9 months. The children were predominantly white Caucasian. Control group children were recruited from four local primary schools in the East of England. Class teachers of this participant group were asked whether the children had any psychological or developmental disorders. None of the children presented with either developmental or psychological disorders. Two children with a non-verbal IQ below 70 were excluded from all studies.

[3] An additional control group of younger hearing children took part in Study 5 (Theory of Mind)

Group matching

Chronological Age

Subsets of this participant pool took part in each of the studies in this thesis, matched for chronological age (CA), gender and non-verbal ability. The studies in this thesis were conducted at different points in time and attrition was dealt with by continuing to recruit new children. Table 1 displays the mean CA and number of children taking part in each group (deaf and hearing controls) for each study. No significant difference in CA between deaf and hearing groups was found (all *p*s >.05).

Table 1.*Mean and SDs of CA (yrs.mths) and Number of Deaf and Hearing Children in each Study*

	Children		
	Deaf	Hearing	
Study 1	8.4 (1.8) (*N* = 30)	8.11 (1.6) (*N* = 32)	*t* (60) = -1.65, *p* = .10
Study 2	8.8 (1.7 (*N* = 27)	9.0 (1.5) (*N* = 26)	*t* (51) = -.865, *p* = .39
Study 3	9.3 (1.6) (*N* = 28)	9.3 (1.8) (*N* = 28)	*t* (54) = -.03, *p* = .99
Study 4	8.6 (1.9) (*N* = 5)	8.2 (1.3) (*N* = 5)	*t* (8) = .33, *p* = .75
Study 5	9.0 (1.6) (*N* = 27)	8.8 (1.6) (*N* = 23)	*t* (48) = .77, *p* =.45

Raven's Progressive Colour Matrices

The children were matched on non-verbal ability based on scores derived from Raven's Coloured Progressive Matrices (CPM) *(*Raven, Court & Raven, 1990). The test comprises 36 items in three sets of 12 matrix designs, assessing non-verbal spatial ability. Ravens Progressive Matrices tests have been shown to be valid when utilised with deaf individuals (Blennerhassett, Strohmeier &

Hibbett, 1994). The instructions are minimal and the task is very visual. Each test item has three pieces and one piece missing. The child is presented with six pieces underneath to choose from to logically complete the pattern of the test item. The test items were presented via a computer interface to increase ease of administration and interest to the child. Each child had to point to the chosen piece, the experimenter clicked on the response and the programme automatically moved onto the next item. The raw scores were then converted into standardised scores. Table 2 displays the mean standardised scores of the whole pool of participants. An independent t-test revealed no significant difference between groups, t (101) = -1.15, p = .26.

Language measures

The deaf children's language ability was measured using the *BSL Receptive Skills Test* (Herman, Holmes & Woll, 1999) and the control group children were tested using the *British Picture Vocabulary Scale* (BPVS) 3rd edition (BPVS III) (Dunn & Dunn, 2009). Deaf children were also tested on lip-reading ability using the *Craig Revised Lip-reading Inventory* (Updike, Rasmussen, Arndt & German, 1992). These measures were chosen in order to gain the best estimate of language ability in each of the groups. Table 2 displays the mean scores for language measures. Both the deaf and hearing control group children scored within the average range on these measures.

BSL Receptive Skills Test

Deaf children who communicated via sign language (including SSE) were tested for their level of receptive skill in the syntax and morphology of BSL with the BSL Receptive Skills Test (Herman et al., 1999). At the time of testing, this was the only available standardised measure that could be used with deaf children (aged 3 to 11) to estimate their 'verbal', or signing, age. Six grammatical features of BSL are assessed by the 40 test items: spatial verbal morphology (e.g. "travel by car"), number/distribution (e.g. "one teddy"), negation (e.g. "not sleep"), size/shape specifiers (e.g. "pencil thick"), noun/verb distinctions (e.g. "boy drink") and handling classifiers (e.g. "eat thin sandwich") (Sutton-Spence and Woll, 1999). The test takes approximately 20 minutes to administer and ends when a child gets four consecutive incorrect answers. The raw score is converted to a standardised score to calculate a child's 'signing age'.

The task was administered by the experimenter following the standardised procedure. The test is signed on a pre-recorded video to ensure consistency in administration. The task was paused after each initial instruction to confirm the children had understood the task. This test begins with a vocabulary check (e.g., the signs for items such as "apple" and "umbrella") to ensure that children are able to both comprehend and generate the signs relating to objects and people that are subsequently used in the test. If a child failed to pass the vocabulary check, the test itself was not administered. Test scores for 34 of the deaf children were obtained. The remaining 8 children did not obtain a sufficiently high score on the vocabulary check to continue with the test. As the test can only be conducted once a year, standardised scores were collected from schools for some of the participants to avoid practice effects and ensure validity.

Craig's Lip-reading Inventory

As the majority of deaf children were oral, they were also tested on their lip-reading ability using the Craig Revised Lip-reading Inventory (Updike et al., 1992). Craig's Lip-reading Inventory tests word and sentence recognition to ascertain the communication level of deaf children. The test includes a word test, used to record selected phonemes, and a sentence test to measure lip-reading for more intricate language patterns. The word recognition task consists of two subsets of words each with 33 items (e.g. “white”, phoneme: /wh/). The sentence recognition task also contains two subsets each with 24 items (e.g. “a frog is hopping away from a boat”). Each word is accompanied by a pencil drawing to account for potential differences in reading ability.

When administering the lip-reading test, the experimenter ensured that the child was sat facing them so that each child was able to clearly see the experimenter’s face. The test began with a sample question to ensure that the task was understood. The experimenter asked “*show me…*” before each test item. A multiple choice response form was provided and the child was asked to point to their response.

British Picture Vocabulary Set

Verbal ability of the control children was tested with the British Picture Vocabulary Scale (BPVS) 3rd edition (BPVS III*) (*Dunn & Dunn, 2009*).* This test measures receptive (hearing) vocabulary of Standard English of children aged 3- 16 years. The test contains full colour pictures. For each test item the test administrator says a word and the child responds by pointing to (or reading the number of) the picture that they think explains the meaning of the word. The test words cover a range of content areas such as actions, animals, toys and emotions, and parts of speech such as nouns, verbs or attributes, with an increasing level of difficulty as the test progresses. The test follows a standardised format of verbal instruction and begins with two test items to check understanding. The raw scores are then converted into standardised scores to calculate a child’s verbal age.

Table 2.*Mean and SD of Non-verbal Ability and Language Measures of Deaf and Hearing Children*

	Children	
	Deaf (N = 42)	Hearing (N = 61)
Non-verbal IQ	95.26 (15.85)	98.61 (13.64)
BSL Receptive Skills	93.94 (19.49) (*N* = 34)	--
Lip-reading	95.74 (21.2)	--
BPVS	--	97.36 (14.12)

Methodology

Ethical statement

This project was approved by the Research Ethics Sub-Committee at Anglia Ruskin University. Informed, written consent was obtained from parents for all children to participate, and additional consent to be videoed was obtained for those children who were filmed. The participant information sheet and consent forms were initially sent to participating schools who in turn forwarded these to the children's parents. Once the parents had consented, schools were contacted and individual testing sessions at the school were arranged. Each study was explained to the children prior to beginning the testing session in the appropriate language (BSL, SSE or English). Written consent was obtained from children aged seven and above. The experimenter checked with the children that they were happy to be filmed, and informed them that they could withdraw at any time.

Design and statistical analysis

This thesis presents five studies with novel paradigms designed to assess different aspects of emotion processing and social cognition in deaf children. Studies 1 and 2 investigate the effect of motion, and study 3 investigates the effect of intensity, on emotion recognition. Studies 4a to 4c are exploratory studies investigating the emotion production abilities of deaf children when initiated by a verbal prompt (4a), a signed emotion story (4b) or through mimicry of facial expressions of emotion (4c). Study 5 investigates deaf children's ToM abilities through first- and second-order false belief tasks. Studies 1, 2, 3 and 5 were assessed through accuracy of response and Study 4 was assessed through how easily recognisable and intense the expressions that the deaf children produced were according to both human raters and face-reading software.

Design

The design of all the studies in this thesis was mixed-model. Group (deaf and hearing) was the dependent variable in each analysis, and the independent variables varied between presentation of face (human vs. cartoon), motion (static or dynamic), emotion (six basic emotions), intensity of expression (subtle or intense) and task of false belief (unexpected location/content, second order). The order of presentation of experimental stimuli was either counterbalanced or randomised to avoid practice and fatigue effects.

Statistical analysis

Where it was possible, parametric tests were applied using repeated measures ANOVAs or independent t-tests. If data did not present a normal distribution (studies 1 -3), logarithmic transformations were applied in order to normalise the data. No differences in the analysis were found so the original data was used throughout this thesis. The human ratings in Study 4 and ToM tasks in Study 5 produced nominal and ordinal data and so non-parametric equivalent tests were carried out. Post-hoc tests were employed to investigate the specific differences between groups. Bonferroni corrections were applied, and effect sizes reported, throughout.

Due to the heterogeneous nature of deaf children, within group differences were explored, regrouping children according to background data collected (e.g. level of deafness, type of hearing amplification, whether or not a family member signed). For all children, further analyses (correlation and linear regression) were carried out to explore the relationship between language, non-verbal ability, age and the independent variables described above. For deaf children, additional background factors such as type of hearing amplification and lip-reading ability were also added as predictors. It should be noted that these comparisons were exploratory in nature due to small sample sizes.

Statistical power

Statistical power is often an issue in research with clinical populations: due to small sample sizes there can be a high degree of variability of individual performance. Low statistical power increases the likelihood of Type II error and so questions the reliability of the results. The novel experimental paradigm created for the studies in this thesis makes it difficult to calculate a prediction of statistical power. A literature review of previous research investigating emotion recognition in deaf children showed that studies have included groups of children with between 18 and 30 participants. The sample of deaf children in this thesis (ranging from 27-30 in each study) was therefore considered sufficient to ensure adequate statistical power

(Hosie et al., 1998; Hoypyan-Misakyan et al., 2009; Ludlow et al., 2010; Most & Aviner, 2009; Most & Michaelis, 2012; Ziv et al 2012).

Outliers

Due to the heterogeneous nature of the population of deaf children, individual differences according to different backgrounds were of particular interest. For this reason, outlier data was not removed for the deaf group of children as these cases may be reflective of this heterogeneity. To reduce the chance of outliers occurring due to boredom, fatigue or failure to understand a task, the experimenter encouraged all children with positive reinforcement, practice items were administered with feedback given, and breaks were allowed within tasks if necessary.

General procedure

All participants were tested individually at school in a quiet room, separate from the main classroom e.g. speech and language therapy room. This provided the children with a space free from distraction from others, but also a familiar environment so to make them feel at ease. For all computer based tasks, the children were seated at approximately 60cm in front of a 14-inch portable computer screen. All testing sessions were carried out by the author of this thesis.

The experimenter communicated with the children in English, BSL or SSE depending on each child's preferred method of communication. The experimenter's signing level (Level 2 BSL) was sufficient to carry out the testing. However, in some cases in which a child's communication was less clear, a teaching assistant experienced in communicating with the child was also present. This was to ensure full understanding and accuracy in interpreting the child's responses.

In the first testing session, participants were tested on non-verbal and verbal ability. This session lasted between 20-30 minutes for all participating children (for those children with a larger vocabulary, the test lasted slightly longer). The additional lip-reading measure administered to deaf children lasted a further 10 minutes. The session began with general conversation to build rapport, the experimenter then explained the session to the child and obtained verbal or written consent (7+). The Ravens CPM was conducted first as children find the interactive element engaging, and then the laptop was removed to avoid further distraction. The children were given short breaks between tasks if necessary. The procedure for subsequent experimental testing sessions can be found in the individual chapters.

Chapter Three

Study One: Emotion recognition of deaf and hearing children

Overview

While deaf children have demonstrated a delay in performance on false belief tasks testing social-cognition ToM (e.g. Peterson & Siegal, 1995, 1998), less clear is their ability to label facial expressions of emotion: a skill thought to be an important aspect of understanding the mental states of others that underpins a more complex understanding of emotions and social-cognitive abilities. This chapter presents a study investigating the emotion recognition of higher functioning deaf children. The understanding of three emotions (happy, sad and angry) was tested using static images and dynamic videos of real human faces, human-like cartoon faces and non-human cartoons. All children benefitted from the use of dynamic stimuli compared to the static presentation of the cartoon faces, and motion also aided emotion identification of human faces for the deaf children. Results indicated that while the deaf children showed a similar pattern of performance to hearing controls for the human faces, they were significantly poorer at recognising emotions in dynamic human cartoons.

Introduction

Facial expressions of emotion are a primary signal in alerting us to the affective states of others, crucial to making inferences in social interactions (Krumhuber et al., 2013). In emotion recognition research, actors display stereotypical configurations of emotions that are thought to be universal, predefined patterns of muscle activation (Ekman, 2003). It is commonly held that being able to label facial expressions of emotion is to show a basic understanding of the mental state of others that is fundamental to later developing a more complex understanding of emotions (Baron-Cohen, 1997; Feshbach, 1982; Frith et al., 1991; Hobson, 1993). Emotions are strongly connected to beliefs and desires (Ashington, 1993; Wellman, 1990); a facial expression sends a signal that indicates whether or not a desire has been fulfilled (e.g. happiness or pride, vs. sadness or disappointment), or whether someone has had a false belief as something unexpected has occurred (i.e. a surprise).

While deaf children have been reported in the literature to display delays in the social-cognitive component as measured by the archetypal false belief task (Peterson & Siegal, 1995, 1998), less clear is the development of the perceptual component, typically measured through emotion recognition. Some evidence suggests that deaf children are delayed or have a deficit in emotion identification in comparison to hearing controls (Dyck & Denver, 2003; Dyck et al., 2004; Ludlow, et al., 2010; Wiefferink et al., 2013). An explanation of these findings has been attributed to the lack of auditory input, providing less opportunity to converse and learn about emotions, leading to a poorer understanding of them (e.g. Peterson & Siegal, 1995; Weisel & Bar-Lev, 1992). Yet studies testing facial emotion recognition in children who are deaf are relatively sparse and have yet to produce conclusive findings given that the results of some studies has indicated deaf children can identify emotions as well as hearing children (Hosie, et al., 1998; Hopyan-Misakyan et al., 2009; Ziv et al., 2013).

Different patterns of performance observed by deaf children compared to hearing children may partly be attributable to the types of stimuli used to test their emotion recognition. First, an important consideration is the potential advantage using real human faces may exhibit over the use of morphed or cartoon faces. The use of 'real human faces' is clearly a better representation of emotion recognition in everyday life. The human face is an important source of social information. Humans have been shown to pay increased attention to faces in comparison to other objects from an early age (Johnson, Dziurawiec, Ellis & Morton, 1991). Our ability to quickly and accurately identify and recognize facial expressions is believed to depend on the tendency to pay attention to faces (Phelps, Ling, & Carrasco, 2006).

Cartoons and synthetic stimuli do not have social cues and key facial features, such as skin wrinkling and bulging that are crucial in natural facial expression (Ekman, Friesen & Hager, 2002). Indeed, the majority of studies that have shown deaf children to have an emotion recognition deficit have utilised cartoon (Ludlow et al., 2010; Schiff, 1973; Wiefferink et al., 2013) or morphed images (Dyck et al., 2004). Ludlow et al. (2010) compared deaf children's ability to recognize the basic emotion expressions of happiness, sadness and anger, and found that deaf children were better at recognizing emotions on real human faces compared to cartoons with similar human-like features. A similar pattern was found for hearing children, yet deaf children's performance was significantly poorer. Although not the specific aim, a recent study by Wiefferink et al. (2013) measured deaf children's emotion recognition with use of line drawings and found they performed significantly worse than controls. Dyck et al.'s (2004) study also found a deficit in deaf children's emotion recognition using the comparatively more complex Fluid Emotions test, which comprises static images of the six basic emotions - happiness, sadness, anger, fear, disgust and surprise - plus contempt. While containing photographs of real faces, the test measures how well a person can detect a change in expression of stimuli which morph from one facial expression of emotion into another. Sometimes the two morphed images differ in nationality and clearly vary hugely from the natural expressions seen in everyday life (Glenn, 2007).

For deaf individuals, the face is particularly important due to its role in the conveying of grammatical and syntactical information of sign language. Signers must rapidly identify and discriminate between linguistic and affective facial expressions of others (Emmorey & McCullough, 2009). In an eye tracking study, Muir and Richardson (2005) found that deaf people have a tendency to fixate on the face rather than hand movements demonstrating that the face is the most important region for sign language, most likely to detect facial movements related to expression and lip-reading patterns. Further evidence of the importance of social information gathered from face, in particular the eyes, was illustrated by Watanabe, Matsuda, Nishioka & Namatame's (2011) study exploring gaze fixation in Japanese deaf and hearing adults. The deaf adults tended to fixate on the eye region, contrary to the hearing adults who fixated on the central part of the face, as is normal within Japanese culture where excessive eye contact is viewed as being rude (Blais, Jack, Scheepers, Fiset & Caldara, 2008). For the deaf community, eye contact has been shown to be vital in communication, and avoidance disrupts communication more significantly than in hearing communities (Mindess, 2006). Deaf individuals may have a particular expertise with faces, as demonstrated by previous findings of superior detection of subtle differences in facial features, distinguishing among similar faces (e.g., the Benton Faces Test) and in discriminating local facial features (Arnold & Mills, 2001; Arnold & Murray, 1998; Bettger, Emmorey, McCullough, & Bellugi, 1997). This suggests that experience with human faces may have a special status for emotion recognition in deaf children and that their ability may depend on the social relevance of the stimuli.

A second consideration is that much of the research addressing emotion recognition in deaf children has largely utilized static photographs (e.g. Hosie et al., 1998; Ludlow et al. , 2010) or morphed pictures (Dyck et al., 2004). Although Dyck et al.'s (2004) stimuli contained motion as the images morph from one to another, viewing the transformation from one face to another does not reflect the experience of emotion perception in everyday life. While studies have shown that static facial features are sufficient for recognizing facial expressions of emotion (e.g. Ellison & Massaro, 1997; McKelvie, 1995; White, 2002), many researchers have argued that the use of static photographs and images lack ecological validity (e.g. Ambadar, Schooler, & Cohn, 2005; Atkinson & Adolphs, 2005). One explanation for this lack of validity is that during social interactions our emotions involve a great deal of movement; therefore it is expected that we learn to discriminate and interpret emotional displays through these interchanges. In comparison, static images largely correspond to clear, distinct and identifiable peaks of socially meaningful movements (Atkinson, Dittrich, Gemmell & Young, 2004).

Some studies have shown the dynamic presentation of facial expressions to improve the recognition of emotional expressions compared to static image presentations (Harwood, Hall, & Shinkfield, 1999). Motion signals associated with the emergence of facial expressions have been shown to be a useful cue in correctly labelling a target subtle emotion expression in adults (Ambadar et al., 2005; Bould & Morris, 2008) and with the use of synthetic stimuli (Wehrle, Kaiser, Schmidt, & Scherer, 2000). Yet the effect of motion has not been uniform across studies. Where clear prototypical human faces have been utilized, a non-motion effect has been found in both adults (Kamachi et al., 2001; Kätsyri & Sams, 2008) and children (Nelson & Russell, 2011). It has been reasoned that when clear facial expressions are posed by human actors, identification of basic emotions is already close to ceiling (Ekman & Friesen, 1978) leaving dynamic information redundant.

There is particular reason to consider dynamic emotion recognition in deaf children given the vital role movement appears to play. For example, the deaf and hard of hearing rely more heavily on motion cues while gauging when to cross a busy road. Deaf people are also reliant on motion for language, both when comprehending critical linguistic information in the hand movements of sign language (Corina et al., 2007), and when reading the movement of lip patterns in the absence of auditory cues (Haxby, Hoffman, & Gobbini, 2002). Deaf signers have been shown to have a strong left hemisphere advantage for motion processing which has been linked to experience in sign language (Bosworth & Dobkins, 2002).

There is logic in supposing that the development of visual attention in the absence of auditory input will be different in deaf children, considering that the coordination of hearing and vision appears to be an important factor in the development of visual attention in hearing children (Smith & Breazeal, 2007). It appears that a greater sensitivity to motion is a notable consequence of the impact of absence on audition in the development of deaf individuals' visual attention. As a result they seem to be more sensitive to some kinds of information: neuroimaging studies and electrophysiological data have shown increased activation in motion sensitive areas (medial superior temporal (MST) area and media temporal (MT) area) in deaf individuals when monitoring motion flow fields to detect velocity changes in peripheral stimuli (Armstrong, Hillyard, Neville & Mitchell, 2002; Stevens & Neville, 2006). Movement may also be important for emotion recognition such that real life facial expressions are dynamic and they indicate moment to moment changes in emotional states of other individuals (Sato & Yoshikawa, 2004). Considering that dynamic properties of facial expressions strongly influence perception of hearing individuals (Kamachi et al., 2001), it is important to address how this might impact upon emotion processing in a deaf population.

A final consideration is the uneven IQ profile amongst studies finding a deficit in deaf children's emotion recognition in facial expressions, meaning that currently the disparity cannot solely be attributed to differences in social cognition (Dyck et al., 2004; Ludlow et al., 2010). Although Ludlow et al.'s (2010) study involved the use of more synthetic stimuli as cartoons were included in addition to human faces, a deficit in the three basic emotions of happiness, sadness and anger was still found even in human faces. It is surprising that no differences in age were found despite the age of the children spanning ten years with the oldest being aged sixteen. It is noteworthy that the mean average IQ of the deaf participants was two SDs below the deaf national average. In contrast, Hosie et al. (1998) tested deaf and hearing children, matched for non-verbal ability, on recognition of the six basic emotions in real human faces and found no overall differences. While the matching task used is based more upon perceptual skills than emotion understanding, no difference was also found on the following task asking children to freely label emotions in faces.

Study 1

The primary aim of the present study was to assess whether differences in emotion recognition would be observed in a group of higher functioning deaf children. The study was in part a replication of a previous study looking at the importance of facial features in emotion recognition (Ludlow et al, 2010). The aim was to investigate emotion recognition for the three basic emotions (happiness, sadness, anger) presented in photographs of real faces, human-like cartoon faces, and cartoon faces that were not human-like. This continuum provides a way to identify the importance of features in processing emotions, such that cartoons contain fewer and more distinguishable features than real faces. In order to account for the reality that emotion is rarely static in nature, the use of dynamic images was included.

A number of predictions were made based on the research here outlined.

Hypothesis one: Deaf children were predicted to display worse performance at identifying emotion in cartoon faces than hearing children, but that performance would be similar between groups for the human faces showing the three basic emotions of happiness, sadness and anger.

Hypothesis two: It was expected for both groups that there would be an advantage for human faces over cartoons.

Hypothesis three: It was predicted that the use of dynamic images would facilitate emotion understanding in both the deaf and hearing children in the cartoon conditions. Considering the importance of motion to deaf children, it was predicted that motion would facilitate deaf children's performance on human faces, but not hearing children's.

Method

Participants

Thirty deaf children (18 girls) aged between 5 years 11 months and 11 years 6 months (mean CA = 8 years 4 months; *SD* = 1 years 8 months) participated in the study. Each child attended one of three mainstream schools with special units for hearing impaired children. The criteria for selection was the presence of prelingual hearing loss at either a moderate-to-severe (>60db; *N* = 20) or profound level (>90 db; *N* = 10) in their better ear. None of the deaf children were native signers. The majority of children were oral in their communication preference (N= 20). The majority of children also used some sign language (either BSL and/or SSE). Ten children communicated mainly via sign (BSL and/or SSE). All children received auditory amplification: 16 children wore cochlear implants and 14 wore hearing aids. None of the deaf participants had known associated medical disorders at the time of testing.

A group of 32 control children (18 girls) with no hearing loss, matched to the deaf children by gender, non-verbal IQ and CA (aged 6 years 1 month - 11 years 9 months: Mean CA = 8 years 11 months, *SD* = 1 years 6 months) also participated in the study. Table 3 displays the mean CA, non-verbal ability and language scores for the deaf and control group participants. There was no significant difference between standardised Raven's CPM scores of the deaf and control group children, t (60) = -1.65, p = .10. The hearing control group was also closely matched in CA to the deaf group with no significant difference between the two groups, t (60) =-1.49, p =.14.

Table 3. *CA, Non-verbal IQ, Verbal IQ and Language Measure Mean Scores and SDs for Deaf and Control Group Children (Study 1)*

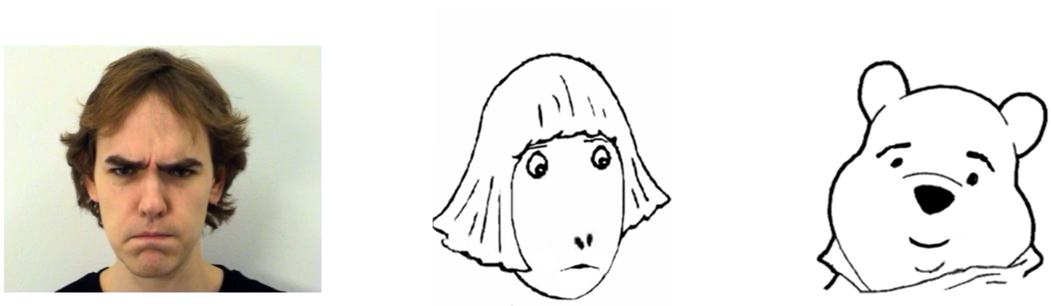
	Children	
	Deaf	Hearing
CA (yrs.mnths)	8.4 (1.8)	8.11 (1.6)
Non-verbal IQ	94.17 (17.67)	101.09 (15.33)
Verbal IQ		104.59 (12.03)
Lip Reading	97.2 (15.59)	
BSL Receptive	96.96 (14.04) (N = 28)	

Note: Standard deviations are in parenthesis.

Materials

Faces: The study's stimuli consisted of 54 black and white images depicting the emotions, happiness, sadness, and anger, presented in three conditions: unedited human faces, human-like cartoon faces and non-human cartoon faces (Figure 1; see Appendix B for full stimuli set). The 18 human faces (nine male) were selected from the Amsterdam Dynamic Facial Expression Set (ADFES) (Van der Schalk, Hawk, Fischer & Doosje, 2011). The dynamic facial stimuli were standardised video clips of North-European people based upon the prototypes of the 'basic emotions' according to the Facial Action Coding System (FACS) Investigator's Guide defined by Ekman et al., (2002). The static stimuli were produced by freezing the film at the apex (point of most intense muscular contraction) of the model's expression.

The human and non-human cartoon faces were adapted from the dataset of Rosset et al. (2008), which had been chosen from cartoon movies. Cartoons were selected according to current popularity with children. The computer animation program, CrazyTalk Animator (Reallusion Inc., 2011), was employed to create the dynamic images, beginning from a neutral expression to display an emotion (happiness, anger and sadness). As the static cartoons were already displaying an animated expression, it was necessary to first edit them to a neutral expression using the freely available photo editing software, GNU Image Manipulation Program (GIMP, 2011). The static images were presented as a screenshot of the fully animated version of the dynamic image. All faces were presented upright, in full face presentation and were cropped at the neckline. Stimuli were displayed in the centre of a 14 inch computer screen using Microsoft Power Point Presentation software. Each static image appeared on the screen for five seconds and the dynamic film clips also lasted for five seconds.



Human Face Human cartoon Non-human cartoon

*Figure 1.*Examples of human, human cartoon and non-human cartoon faces

Design

The study's design was mixed-model with a 3 x (Presentation: Real vs. Human vs. Non-Human) x 2 (Motion: Static vs. Dynamic) 2 x (Participant: Deaf vs. CA). The first two factors were within participants and the third factor was between participants. The trials were randomized into three versions of presentation (A, B, C) for both the static and dynamic presentations. The order of these presentations was counterbalanced between participants. Whether the static or dynamic presentation was initially shown was also counterbalanced.

Procedure

The children were asked to identify the emotion displayed in each image as happy, sad or angry, displayed on the screen of a portable 14-inch computer. In order to ensure that participants understood the test instructions, they were presented with 3 training trials with feedback. Following this, they were presented with 108 trials corresponding to 2 blocks of 54 trials: one containing static human faces and one containing dynamic human faces. Each block comprised six human faces, six faces of human cartoons and six faces of non-human cartoons, each presented as happiness, sadness and anger. Stimuli were displayed on the screen until the subject responded.

A short break was given between each block if necessary. Verbal or signed responses were recorded by the experimenter. A score of one was given for a correct response and a score of zero if incorrect. The experimenter's signing level (BSL Level 2; minimum requirement for teachers of the deaf) was proficient enough to interpret the signed responses.

Results

The number of errors in the recognition of each emotion was the main unit of measurement[4]. Table 4 displays the percentage means and standard deviations for the number of errors for Presentation of face (real face, human cartoon, non-human cartoon) and level of Motion (static or dynamic) for deaf and control group participants. The mixed analysis of variance revealed a significant main effect of Participant, F (1, 60) = 4.20, MSE = 3.83, p = .05, η^2 = .07, showing that overall deaf children were less accurate at identifying emotions than hearing children (mean difference = .416, p =.05). A main effect of Presentation was found, F (2, 120) = 179.99, MSE = 1.36, p< .001, η^2 = .75; overall, real faces had significantly less errors than human (mean difference = 1.82, p<.001) and non-human cartoon faces (mean difference = 2.76, p<.001), and cartoon faces had significantly less errors than non-human cartoon faces (mean difference = .95, p<.001). A main effect of Motion was also present, F (1, 60) = 87.02, MSE = 1.08, p< .001, η^2 = .59, so that overall, static faces had significantly more errors than dynamic faces (mean difference = 1.01, p<.001).

[4] The error scores presented positive skewness in both groups so the data was subjected to a logarithmic transformation plus a constant (lg10 +1) in order to normalise the data. No differences in the analysis were found so the original data was used in the presented analysis and throughout this thesis.

Table 4. *Mean and SD of Errors by Participant, Presentation and Motion (Max.18)*

	Real human		Human-Cartoon		Non-human cartoon		Total	
	Static	Dynamic	Static	Dynamic	Static	Dynamic	Static	Dynamic
Deaf	.37 (.72)a	.07 (.25)b	2.77 (1.68)a	1.87 (1.68)b	3.7 (1.64)a	2.67 (1.79)b	6.83 (2.89)	4.6 (3.47)
Hearing	.22 (.55)a	0.03 (.18)a	2.63 (1.62)a	.69 (.86)b	3.53 (1.37)a	1.84 (.99)b	6.38 (2.8)	2.72 (1.49)
Total	.29 (.64)	.05 (.22)	2.69 (1.64)	1.26 (1.44)	3.61 (1.5)	2.24 (1.48)	6.6 (2.83)	3.63 (2.72)

Note: Standard deviations are in parenthesis. For each type of face (Real, Human-Cartoon, Non-Human cartoon), means in the same row with different subscripts are significantly different with Bonferroni adjusted significance level $p < .02$.

The Participant x Motion interaction was significant, F (1, 60) = 5.94, MSE = 1.08, p = .02, η^2 = .09; post-hoc analysis with Bonferroni corrections showed no significant differences between the groups when comparing static presentation, t (60) = .64, p = .53; Cohen's d = .17, but that deaf children made significantly more errors than hearing children in the dynamic presentation, t (60) = 2.88, p = .006; Cohen's d = .70. Importantly, the Presentation x Motion interaction was significant, F (2, 120) = 17.02, MSE = .80, $p < .001$, η^2 = .22. Post-hoc tests with Bonferroni corrections revealed that identification of emotions was significantly and consistently lower in static faces compared with dynamic faces across the three presentations (human faces: t(61) = 3.22 p=.002, Cohen's d = .50; human cartoon: t(61) = 6.67, p <.001, Cohen's d = .93; and non-human cartoon: t(61) = 6.92, p < .001, Cohen's d = .92). The Presentation x Participant interaction was not significant, F (2, 120) = 1.95, MSE = 1.36, p = .15, η^2 = .03.

All these effects were qualified by a significant three way interaction between Presentation × Participant × Motion, F (2, 120) = 3.33, MSE = .80, p = .04, η^2 = .05. Post-hoc analyses with Bonferroni corrections (adjusted significance level of .008) revealed there were no significant differences between the deaf and hearing children when identifying real faces, either in the dynamic (t (60) = .20, p = .52, Cohen's d =.18), or the static presentation, (t (60) = .92, p = .37, Cohen's d =.23). There were also no significant differences between deaf and hearing children when identifying non-human cartoon faces, either in the dynamic (t (60) = 2.63, p = .03, ns, Cohen's d = .57) or static presentation (t (60) = .44, p = .66, Cohen's d =.11). Importantly, results showed that deaf children made significantly more errors than hearing children in the human cartoon faces only in the dynamic presentation, t (60) = 3.52, p =.001, Cohen's d =.88 ; but this difference was not significant when comparing the static presentation, t (60) = .34, p = .74, Cohen's d = .08.

To investigate the effect of IQ, BSL receptive language, lip-reading and CA on performance of the deaf children Spearman Rank Correlation tests were computed. The results revealed that none of these correlations were significant (all *ps*> .05). Similarly, for hearing control children, IQ, BPVS and CA were not significantly correlated with performance (all *ps*> .05).

Heterogeneity of deaf children

Further analyses were carried out to explore whether differences occurred in deaf children's overall performance in emotion recognition depending on the type of hearing amplification (CI or HA), level of deafness (moderate-severe or profound), communication preference (oral or sign) and whether or not family members signed. Table 5 displays mean scores for total static and dynamic errors for each sub-group.

Table 5. Mean and SDs for Total Static and Dynamic Emotion Recognition Errors for Subgroups of Deaf Children (Study 1)

(Divided by hearing amplification, level of deafness, communication preference, and whether have signing family members)

	CI or HA		Level of deafness		Communication		Signing family members	
	CI (*N* = 14)	HA (*N*= 16)	Severe (*N* = 20)	Profound (*N* = 10)	Oral (*N* = 20)	Sign (*N* = 10)	Yes (*N* = 20)	No (N = 10)
Static	1.57 (1.0)	1.56 (.77)	1.55 (.79)	1.6 (1.05)	1.55 (.89)	1.6 (.88)	1.78 (.80)	1.15 (.88)
Dynamic	1.04 (.91)	.91 (.86)	.95 (.86)	1.0 (.94)	1.0 (.90)	.90 (.84)	1.03 (.88)	.85 (.88)

Note: Standard deviations are in parenthesis.

The possible difference in performance based on the severity of hearing loss was examined comparing the children with a hearing loss classed as moderate-to-severe and profound. Results revealed no significant differences in recognition of static, t (28) = .09, p = .93, Cohen's d = .03; or dynamic faces, t (28) = .23, p = .82, Cohen's d =.09. Further analysis was performed on the sample of deaf children in order to investigate whether signing ability, preferences in communication style (oral vs. signing), and the type of hearing aid the children had moderated any of the effects reported. For signing ability, deaf children were grouped into those who had signing family members and those who did not. Errors of static and dynamic faces were compared across groups. The analysis suggested that presence of signing family members did not have a significant effect on emotion recognition in static images, t (28) = .85, p =.41, Cohen's d = .31; or dynamic images, t (28) = .340 p = .74, Cohen's d = .13.

Preference in communication (oral (N = 20), signing (N = 6) or both (N = 4)) was analysed. As the majority of children in this study preferred to communicate orally, preference for oral communication was compared with the other two types to create a meaningful comparison group. Results revealed that the type of preferred communication did not have an effect on the recognition of static, t (28) = .18, p = .86, Cohen's d = .07; or dynamic faces, t (28) = .11, p = .91, Cohen's d = .31. Analysis investigating the effect of type of hearing amplification revealed no differences between those with hearing aid and those with cochlear implants on the recognition of static, t (28) = -.04, p = .97, Cohen's d = .72; or dynamic faces, t (28) = -.28, p = .78, Cohen's d = .26.

Discussion

Studies where emotion deficits in deaf children have been reported have tended to include a sample of children with lower IQs than the national average, so these results may not reflect what is typical of the deaf population (e.g. Dyck et al., 2004; Ludlow et al., 2010). The three aims of the current study were to assess whether differences in emotion recognition would be observed in a group of higher-functioning deaf children, and to consider the importance of motion cues (static versus dynamic) and social relevance (human faces in comparison to cartoon faces) in emotion recognition ability.

This was the first study to examine the effect of dynamic displays of emotion on deaf children's emotion recognition. The current findings indicate that the deaf children followed a similar pattern to their hearing controls in demonstrating a significant advantage for both the real faces and the use of dynamic displays in processing emotion (Ambadar et al., 2005). Reason dictates that dynamic faces have greater ecological validity and would be easier to interpret as everyday interactions largely involve dynamic face processing. Yet despite testing a group of deaf children with average non-verbal IQ, they were still significantly poorer overall at identifying basic emotions compared with their hearing controls.

As predicted by hypothesis one, the results replicate those previously reported in some of the literature and appear to suggest that deaf children have some differences relative to hearing controls in their emotion recognition ability when the stimuli utilized is either cartoons or morphed faces as opposed to real human faces (e.g. Dyck et al., 2004; Ludlow et al., 2010; Wiefferink, et al., 2013). However, it is important to raise caution in interpreting the results as an actual deficit. When looking at the margins of error, even though the deaf children were significantly poorer than their hearing controls, they were still able to identify a substantial number of emotions correctly. In particular, the difference in recognising the human faces was not significantly different between the deaf and hearing control group as was predicted; error rates were low and demonstrated near ceiling effects, as has been found in other previous studies on deaf children's emotion recognition using prototypical human faces (Most & Aviner, 2009; Hopsan-Miskyan et al., 2009; Hosie et al., 1998; Ziv, et al., 2013).

By using the continuum of stimuli of real faces - human cartoon - nonhuman cartoon faces, the importance of facial features in the ability to recognize emotions was able to be tested. The cartoon faces contained fewer and more distinguishable features than real faces and, in line with hypothesis two, both deaf and hearing children were poorer across the trials using cartoon faces. An advantage for real over cartoon faces may reflect the importance of children's expertise with features of real faces. Clearly, real faces hold more important information for emotion recognition than cartoons and this difference may be particularly significant to individuals who are deaf, due to their reliance of certain facial expressions for both linguistic and affective markers (Corina et al., 2007). It appears that with increased social relevance of the stimuli, increased performance in emotion recognition is found in deaf children.

The results of Study 1 partly support the view that motion will aid deaf children in emotion identification (hypothesis three), in particular, in disambiguating the cartoon emotion expressions (Bould & Morris, 2008; Kätsyri & Sams, 2008; Wehrle et al. 2000). For the deaf children in this study, the advantage for dynamic images existed in human faces also, whereas this was not the case for the hearing controls. The result for hearing children replicates results found in previous research where clear prototypical displays of static images reduced the advantage of dynamic images (Nelson & Russell, 2011). However, the effect size of motion was not as great for deaf children as it was for hearing controls in improving emotion identification in cartoons, which is interesting as motion is a vital cue to perception in the world for deaf individuals. The lack of certain facial features in the cartoon stimuli, such as skin wrinkling and bulging that are key in natural facial expression (Ekman et al., 2002), could explain poorer identification rates in cartoons and point to an expertise with the face in children. Indeed, deaf children's relative difficulty in identifying emotions in cartoons in comparison to hearing children, and the advantage of dynamic images for emotion recognition in human faces, may further highlight their reliance on the non-verbal and certain facial expressions of real human faces (Corina et al., 2007).

Alternatively, a relative difficulty in identifying emotion expressions in cartoons, even when in motion, may reflect that deaf children watch fewer cartoons in comparison to hearing children. This seems unlikely, however, as deaf children have been shown to watch as much television, if not more than their hearing peers (Liss & Price, 1981). Yet hearing children are able to follow cartoons before they develop reading skills and are therefore more likely to be able to link the emotions displayed in cartoons with other emotion cues present in speech, found in the content of language, emotional prosody and in contextual/pragmatic cues. Deaf children are reliant on captions for such information and yet are known to be delayed in their reading abilities (Lewis & Jackson, 2001). Moreover, it has also been identified that traditional captioning omits important information such as information about the emotive characteristics of the dialogue or music (Fels, Lee, Branje & Hornburg, 2005). As a result, deaf children may watch cartoons, but subtitles or the narrative and intentions and actions of the characters may be misunderstood (Lewis & Jackson, 2001).

A further alternative explanation of deaf children's higher error rates in identifying emotions in cartoons in Study 1 is that it could signal a difficulty with more subtle emotions. Despite containing roughly similar FACS units, as a result of technical limitations the cartoon stimuli were likely to be less intense than the natural human faces (Kätsyri & Sams, 2008). In everyday life we more frequently experience more subtle and less intense changes in emotion. Intensity has been shown to influence recognition accuracy in children's identification of emotion expressions and improve with age (Gao & Maurer, 2010; Montirosso et al., 2010). Dynamic images have been shown to enhance emotion identification in subtle expressions of low intensity (Ambadar et al., 2001), therefore it is conceivable that because the cartoon faces in study 2 contained static cues that were subtle, the dynamic effect was pronounced. As the effect size was greater for the hearing control children than the deaf children it calls into question whether dynamic presentation of subtle *human* faces would provide a sufficient cue to allow for correct identification for deaf children.

A second limitation of the present study is the near ceiling effects in identification, particularly in the human facial expressions of emotion, suggestive that the task was too simplistic to effectively test deaf children's emotion recognition abilities. The results may suggest that deaf children's emotion processing of human faces of emotion is intact. Alternatively it could be an artefact of an inconsistency between experimental stimuli. The human faces utilized in this study were presented in colour while the human cartoon and non-human cartoon faces were presented in black-and-white. There is evidence to suggest that stimulus salience - in this instance, colour – has an impact on attention (Parkhurst, Law and Niebur, 2002; Treisman and Gelade, 1980). Yet it is also reasonable to expect that deaf children can interpret the three most basic emotions of happiness, sadness and anger in clear and exaggerated displays in human faces as shown in some previous studies (e.g. Hosie et al., 1998). What remains to be seen is whether the deaf children would be able to perform accurately with more complex emotions in real, dynamic faces, such as fear, disgust and surprise.

In sum, the results of Study 1 suggest that, while deaf children were poorer at recognising the dynamic version of cartoons than hearing children, recognition of emotion in human faces – whether presented in a static form or in motion – is intact. The near ceiling results for human faces, however, may be precluding differences between groups and so a more challenging emotion recognition task inclusive of additional, more complex emotions is necessary. For both groups, motion was an aid to recognition for the synthetic cartoon stimuli. Motion appeared to improve emotion recognition in human faces for deaf children, but again more investigation is necessary given the low error scores for both static and dynamic stimuli for deaf children. The subtle expressions in the cartoon static stimuli proved difficult for both groups to identify emotions, but the dynamic cue was not as great for deaf children as it was for hearing children. This indicates that for deaf children, additional cues that are provided from human faces are more essential for emotion identification.

Chapter Four

Study Two: Emotion recognition of deaf and hearing children in real dynamic faces

Overview

In the previous chapter it was found that deaf children's facial emotion recognition performance was worse than that of the hearing children's for cartoon faces but not human faces, and that the dynamic presentation facilitated their performance. In this chapter, Study 2 further explores deaf children's facial emotion identification of an additional three emotions – fear, disgust and surprise – along with happiness, sadness and anger. Emotion recognition was tested in static (still photographs) and dynamic (video clips) displays. Results revealed no overall difference between the deaf and hearing control group children, but deaf children performed worse on the emotion, disgust. Dynamic presentations were shown to significantly aid deaf but not hearing children's emotion recognition.

Introduction

Study 1 found that deaf children performed better at emotion recognition of the three most basic emotions – happiness, sadness and anger - when presented in a dynamic rather than a static presentation of real human faces. It is arguable that showing at least all six of the basic emotions gives greater ecological validity (Matsumoto & Ekman, 2004). This chapter focuses on deaf children's emotion recognition of all six of the basic emotions in real human faces.

Ekman (1999) suggested that there are universal visual cues for the perception of happiness, sadness, anger, fear, disgust and surprise, the key facial indicators being the eyes and the mouth. Facial emotion recognition research with typically developing hearing children has shown that the age at which these emotions can be reliably identified varies according to age. It has been shown that typically developing infants as young as three or four months of age can distinguish static displays of happy, sad and surprised faces (Young-Browne et al., 1977) and dynamic displays of happy and angry faces by seven months of age (Soken & Pick, 1992). Widen and Russell (2003) demonstrated that by the age of four years, typically developing children are able to freely label 'prototypical' (exaggerated, strong) displays of happiness, anger and sadness with near perfect accuracy, and are becoming more proficient at recognising fear and surprise. Ekman (2007) proposed that happiness is recognised earlier because it primarily involves recognition of the mouth movements, whereas the affective facial expression of fear is recognised later due to the required integration of information from the mouth, eyes and forehead.

Only a handful of studies have included all six of the basic emotions when investigating the emotion recognition abilities of deaf children using human faces. These studies vary considerably in terms of stimuli used and methodology adopted making a comparison of studies challenging. In a recent study, Ziv et al., (2013) found deaf and hearing children to be similar in their ability to label emotion expressions, however unlike other studies, the scoring system allowed points for a 'partially' correct answer, meaning an emotion of the same valence was credited (e.g. 1 point rather than the full 2 points was given if a child labelled an emotion as 'sad' rather than 'angry'). Hosie et al. (1998) similarly found deaf and hearing children to be comparable on both matching and labelling tasks. Moreover, while the deaf children, like the hearing children, found disgust and fear most difficult to correctly identify, they were found to be superior to the hearing children at labelling disgust and fear. Hosie et al. reasoned that deaf children were relatively better at recognising the two emotions most difficult for hearing children, as usually hearing children identify emotions with the auditory as well as visual cues in everyday life. Conversely deaf children, reliant on visual cues in emotion processing, may show an enhanced sensitivity to facial expressions. It is noteworthy that when emotion matching tasks have preceded emotion labelling tasks identification rates have been higher (Harrigan, 1984).

Yet, as aforementioned, some studies investigating emotion recognition in deaf children have shown a deficit in comparison to hearing children. Dyck et al.'s (2004) study was comparatively more difficult than other studies. Dyck et al. compared deaf and hearing children on a composite test – the Fluid Emotions test - rather than looking at individual emotions; the more complex emotion of contempt was included, which has been shown to be recognised later than the basic emotions such as happiness, fear and anger (De Sonneville et al., 2002; Gross & Ballif, 1991; Herba & Philips, 2004). Additionally, children were assessed based on speed of response as well as accuracy, which places a higher demand on their processing skills.

Another theme in the research addressing deaf children's emotion understanding is the crucial contribution of language on their development of emotions. Interestingly, when the samples in Dyck et al.'s (2004) study were matched for language ability, the deaf children and adolescents' performance was not significantly different from the controls'. This suggests that either the test materials may have been too reliant on language, or that language is an important factor in recognising and understanding others' emotions. Studies have shown that deaf children of hearing parents have fewer and less complex explanations of their own and other people's emotional displays than deaf children of deaf signing parents (Marschark, 1993). It has been suggested that this difference can be explained by the lack of opportunities to converse and to overhear others' conversations as a result of reduced auditory input (Woolfe et al., 2002). These findings are also supported by results showing that once a common language between parents and children is present, for example sign language in parents of deaf children, it provides an opportunity for the children to talk and learn about emotions (Meristo et al., 2007).

Focusing on the relationship between early language development and better emotion understanding, many researchers are beginning to explore the broader effects of auditory amplifications, such as CIs or HAs on deaf children's emotional and social development (Wang, Su, Fang, & Zhou, 2011). Both CI and HA are one of the most significant advances in recent decades, allowing deaf children earlier access to some degree of spoken language. Importantly, an increasing number of deaf children grow up in hearing families and attend mainstream schools (Lachs et al., 2001), with some literature showing the effectiveness of these devices on their perception of speech (Lee et al., 2010; Sharma et al., 2002). However, relatively few studies have addressed their effect on emotion recognition with the small amount of studies carried out yielding mixed results. For example, some studies have found no differences in facial emotion recognition when comparing a group of older deaf children with early amplification (7-17 years old with CI and HA compared to age matched hearing children; Hopyan-Misakyan et al., 2009; Most & Aviner, 2009). In contrast, when younger groups of children have been compared, pre-schooler users of CI or HA with age matched hearing children, results showed that hearing children performed significantly better than those with CI or HA; this suggests that there was a delay in pre-schoolers with CI or HA on facial emotion recognition (Wang et al., 2011).

Some accounts of typically developing children's emotion development posit that their labelling 'errors' reveal how they understand emotions (Gao & Maurer, 2009; Widen & Russell, 2003). Initially, children only use two labels (usually 'happiness' and 'sadness') because their understanding of emotions relates to positive and negative valence rather than the discrete categories that are later used as adults (Widen & Russell, 2008a). Hosie et al. (1998) is the only study to date to look at deaf children's error patterns in emotion recognition. The results suggested a similar pattern of errors to hearing children. Younger children tended to label negative emotions as sad; disgust was confused with anger, and fear with surprise, reasoned as being similar on a dimension of pleasure and arousal (Bullock & Russell, 1984).

Another possible explanation for errors is that the static images used in emotion recognition research do not adequately capture expressions seen in everyday life It has been questioned whether static images are sufficient in terms of ecological validity given that a key feature of facial behaviour is its dynamic nature (see chapter four for a review). It is important to consider dynamic displays not only because of higher ecological validity, but also because of the differential neural activation that is evoked (Atkinson & Adolphs, 2005; Krumhuber et al., 2013). Importantly, a number of neuroimaging studies have revealed higher brain activity in regions linked to the processing of social (superior temporal sulci) and emotion relevant (amygdalae) information when viewing dynamic rather than static expressive faces (Kilts et al., 2003; Klesser et al., 2011). This neuroscientific evidence is suggestive of a neural network that facilitates social interaction by helping us to understand others, identify their needs and predict their actions (Krumhuber et al., 2013). Given deaf children's delays in cognitive tasks assessing ToM (the *false belief* task e.g. Peterson & Siegal, 1995), it is of particular importance to investigate emotion recognition of more socially valid dynamic facial expressions.

Previous studies investigating deaf children's emotion recognition had utilised static (e.g. Hosie et al., 1998; Ziv et al., 2013) or morphed pictures (Dyck et al., 2004), yet it has been suggested that the use of 'real people' is required to prompt stronger effects with dynamic stimuli (Sato, Fujimura, & Suzuki, 2008). Motion has previously been shown to be a vital cue for deaf people in interpreting lip-reading and hand signals in sign language (Corina et al., 2007; Haxby et al., 2002), and the results of Study 1 suggest this may also be the case for recognising emotion. Study 1 found that deaf children performed better at emotion recognition of the three most basic emotions – happiness, sadness, anger - when presented in a dynamic rather than a static presentation of real human faces.

Study 2

Typically developed children have difficulty in producing and comprehending acceptable verbal labels for expressions of disgust, fear and surprise (e.g., Harrigan, 1984; Markham & Adams, 1992; Michalson & Lewis, 1985). In order to gain a better understanding of deaf children's recognition of facially expressed emotions, Study 2 explored all six of the basic emotions: surprise, fear and disgust, in addition to happiness, sadness and anger, using both static and dynamic images of real faces. The human faces were selected from the ADFES (Van der Schalk et al., 2011), chosen because the set was carefully developed to represent the prototypes of the universal emotion signals based on the FACS (Ekman & Friesen, 1978). To our knowledge, it is the only standardized set of faces that contains filmed, natural expressions of 'real people'.

The following hypotheses were drawn on the basis of previous research.

Hypothesis one: Motion will improve emotion recognition in deaf children.

Hypothesis two: The more complex emotions of fear and disgust will be comparatively more difficult for all children. Deaf children will be poorer at these more complex emotions than hearing children due to fewer opportunities to discuss emotions.

Method

Participants

Twenty-seven deaf children (16 female) aged between 5 years 9 months and 11 years 6 months (*M* = 8 years 8 months; *SD* = 1 year 7 months) took part in the study. All deaf children were selected from the same schools and had the same pre-lingual loss characteristics as outlined in Study 1 (21 children had moderate-to-severe hearing loss and 6 had profound hearing loss). None of the children were native signers and the majority of children were oral in their communication preference (*N* = 21). Only two deaf children communicated mainly in BSL and four used a combination of oral and BSL. For the purpose of analysis, these six children were grouped as 'signers'. All children had auditory amplification: 16 children wore hearing aids and 11 had cochlear implants. None of the children had any identified additional learning difficulties in addition to their deafness.

A group of 26 control children with no hearing loss (13 female), aged between 6 years 1 months and 11 years 2 months (*M* = 9 years 0 months; *SD* = 1 year 5 months), also participated in the study. The control group was matched to the deaf group of children on CA. Mean scores for CA, non-verbal IQ and language measures for both groups are shown in Table 6. An independent t-test confirmed a non-significant difference between deaf and hearing children demonstrated that the groups were well matched on CA, t (51) = -.865, p = .39. However, the hearing control group children had significantly higher non-verbal IQ scores than the deaf children, t (51) -2.07, p =.04.

Materials

The study's stimuli comprises 30 unedited videos of five actors (three male) portraying the six 'basic emotions': happiness, sadness, anger, disgust, fear and surprise. The videos were selected from the ADFES (Van der Schalk et al., 2011) and lasted five seconds each. The static version of the videos was created using the same procedure as Study 1. All faces were presented in full colour, in full face presentation, and were cropped at the neckline (Figure 2). Stimuli were displayed in the centre of a 14 inch computer screen using E-Prime v2.0 Professional (Schneider, Eschman & Zuccolotto, 2002).

Figure 2. Real human face stimuli displaying prototypical basic emotions (from top left to right) happiness, sadness, anger, fear, disgust and surprise from ADFES (Van der Schalk et al., 2011)

Design

The study adopted a 6 (Emotion: happiness, sadness, anger, disgust, fear, surprise) x 2 (Motion: static vs. dynamic) x 2 (Participant Group: Deaf vs. Hearing) mixed-model design. The factors, Emotion and Motion, were within participants and the third factor, Participant Group, was between participants. The order in which the trials were presented was randomized across the children taking part in the study. The order of presentation (static or dynamic) was counterbalanced.

Procedure

To ensure that all children understood the task, an adaptation of the Emotion Vocabulary Test (EVT, Dyck, Ferguson & Shochet, 2001) was used as a pre-test. The EVT is a 24-item test of a person's ability to define emotion words (e.g. "what does angry mean?"). Children were asked to define (either verbally or with sign language) the six emotions referred to in this study in the order presented in the EVT (fear, sadness, happiness, anger, surprise and disgust). Questions were open-ended followed by probing questions to further understand and eliminate ambiguities of a child's response. If the child did not appear to understand the emotion word stated, a different form of the lexeme would be presented (e.g. 'disgusting' instead of 'disgust').

Responses were noted on a score sheet and scored using a 3-point scale using the scoring key provided (Dyck et al., 2001): 0 for an incorrect response, 1 for a partially correct response, and 2 for a satisfactory response (maximum = 12). All participants scored 50% or above on this test. Three deaf children were excluded from the study because of scores <50% on the EVT. Table 6 displays the mean scores on the EVT for deaf and hearing children. Although the deaf children had sufficient understanding of the emotion vocabulary, the hearing children scored significantly higher on the EVT, t (51) = -3.46, p = .001.

Table 6. CA, *Non-verbal IQ, Verbal IQ, Language Measure and EVT Mean Scores and SDs for Deaf and Control Group Children (Study 2)*

	Children	
	Deaf	Control
CA (yrs. mnths)	8.8 (1.7)	9.0 (1.5)
Non-Verbal IQ	92.52 (17.36)	101.15 (12.59)
Verbal IQ		104.12 (12.43)
Lip Reading	99.93 (18.19)	
BSL Receptive	95.52 (12.87) (N = 25)	
EVT	9.67 (1.9)	11.12 (.99)

Note: Standard deviations are in parenthesis.

Following this, participants were asked to categorise the emotions presented as happiness, sadness, anger, disgust, fear or surprise. The children were seated at approximately 60cm in front of a 14-inch portable computer screen on which the stimuli were displayed. In order to ensure that participants understood the test instructions, three training trials with feedback preceded the test trials. The test itself consisted of two blocks (one static and one dynamic) each containing 30 trials, showing five of each of the six emotions.

Each stimulus was presented on the screen one at a time in a random order. The videos lasted for five seconds beginning from a neutral pose to the apex of the expressed emotion, and the static faces were also each presented for five seconds. In the dynamic block of trials, a fixation cross was initially presented. Participants were required to press the space bar to begin the video clip. A prompt card with the emotion words and iconic faces was provided so to remind the children of the response options. Verbal or signed responses were recorded by the experimenter. A score of one was given for a correct response and a score of zero if incorrect. Different lexical forms of the target emotion word were accepted as correct as well as a number of synonyms (e.g., cross and furious for anger; 'yucky' for disgust; frightened and scared for fear; and shocked for surprise). The children had a short break between the blocks if necessary.

Results

Accuracy

The EVT was used as a control measure to confirm that all the children had sufficient vocabulary to name each emotion. Differences in the standardized non-verbal IQ scores between the hearing and deaf children were analysed first using an independent samples t-test. Results showed that deaf children had significantly lower scores than hearing children, t (51) -2.07, p =.04. The number of errors was analysed using a mixed analysis of covariance, including the non-verbal IQ score as a covariant in order to control for the differences in non-verbal ability between the groups. Table 7 displays the mean and SD errors for each Emotion (happiness, sadness, anger, disgust, fear, and surprise) and level of Motion (static or dynamic) for deaf and control group participants. The analysis revealed that there was no significant main effect of Participant group, F (1, 50) = 3.02, MSE = 2.73, p = .09, η^2 = .06, suggesting that overall, deaf children's performance on emotion recognition was not significantly different from that of the hearing control children. There was also no main effect of Motion, F (1, 50) =.71, MSE = .47, p =.40, η^2 =.01, meaning that the dynamic presentation gave no advantage to task performance.

There was a significant interaction between the covariate, non-verbal IQ, and Emotion, F (5, 250 = 3.08, MSE = 1.61, p = .01, η^2 = .06, but the main effect of Emotion was still significant, F (5, 250) = 4.42, MSE = 1.61, p = .001, η^2 = .08, showing that some emotion expressions were more easily identified than others. Most accurately identified was happiness, followed by anger, sadness, surprise, disgust and then fear. Post hoc tests with Bonferroni corrections (adjusted level p <.003) showed that happiness was significantly more easily recognised than all other emotions except surprise (p = .005). Fear and disgust were significantly less accurately recognised than any other expressions, although error scores for fear and disgust were not significantly different from one another.

Table 7. *Mean and SD of Errors in Identifying Emotions by Participant and Motion*

	Deaf		Hearing		Total	
	Static	Dynamic	Static	Dynamic	Static	Dynamic
Happy	.07 (.38)	0 (0)	0 (0)	0 (0)	.04 (.27)	0 (0)
Sad	.33 (.55)	.37 (.74)	.15 (.37)	.65 (.80)	.25 (.48)	.51 (.78)
Anger	.41 (.75)	.19 (.0)	.23 (.43)	.19 (.49)	.32 (.61)	.19 (.44)
Disgust	1.93 (1.84)	2.04 (1.95)	.77 (1.11)	.88 (1.42)	1.36 (1.62)	1.47 (1.79)
Fear	2.07 (1.49)	1.26 (1.43)	2.04 (1.73)	1.88 (1.42)	2.06 (1.60)	1.57 (1.45)
Surprise	.78 (1.33)	.59 (1.12)	.23 (.99)	.15 (.78)	.51 (1.2)	.38 (.99)

Note: SDs are in parenthesis.

The results revealed a significant interaction of Emotion and Participant group, F (5, 250) = 5.95, MSE = 1.61, p<.001, η^2 = .11. Post-hoc comparisons with

Bonferroni corrections (adjusted significance level p <.008) displayed a similar profile to hearing children for deaf participants for happiness, sadness, anger, fear and surprise, however, the hearing children's performance was superior to deaf children for disgust, t (51) = -2.84, p = .006, Cohen's d =.78. There was also a significant interaction of Motion and Participant group, F (1, 50) = 6.25, MSE = .47, p =.016, η^2= .11. Post hoc tests with Bonferroni corrections (adjusted significance level p <.03) showed that deaf children made more errors in static displays than hearing children, t (51) = -2.46, p = .017, Cohen's d = .68; but there was no significant difference in error scores for dynamic displays, t (51) = -.84, p = .40, Cohen's d = .22. Deaf children made significantly fewer errors in dynamic than static displays, t (51) = -2.23, p = .03, Cohen's d = .33; but there was no significant difference between static and dynamic displays for hearing children, t (51) = .88, p = .39, Cohen's d = .15. The interaction of Motion x Emotion, F (5, 250) = .50, MSE = .44, p =.78, η^2 = .01, and the three-way interaction between Motion, Emotion and Participant group, F (5, 250) = 1.12, MSE = .444, p = .35, η^2 = .02, were not significant. Non-verbal IQ did not moderate any further effects, all F <1.08, all p >.30).

Factors predicting performance

Further analysis was conducted to investigate the relationship between CA, non-verbal IQ, language (BSL receptive test for deaf children and BPVS for hearing children) and overall performance for both groups. As there was a significant negative correlation between static and dynamic total of errors for both deaf (r =-.71, p <.001) and hearing control group children (r =-.71, p < .001), a combined total error score was calculated. While the deaf children had some understanding of each of the emotion terms, the hearing children scored significantly higher on the emotion vocabulary test than deaf children (*t* (51) = -3.46, *p* = .001, Cohen's *d* = .96); therefore, emotion vocabulary was added as a predictor. For the deaf children, lip reading ability and the type of auditory amplification (coded as 0 = Cochlear implant, 1 = Hearing aid) were also added as predictors (for mean emotion recognition scores, see Table 8). Significant moderate negative correlations were found between total number of errors made by the deaf children and CA (r = -.44, *p*= .02) and emotion vocabulary (r = -.43, p =.03). In addition, a significant moderate positive correlation was found between total number of errors and hearing amplification (r = .56, *p* = .03), suggesting more errors were made by HA wearers. A regression analysis revealed that for deaf children's overall performance (R^2= .57, F = 3.93, MSE = 18.95, *p* = .011), the type of hearing amplification was a significant predictor (β =- .55, *p* = .003), suggesting an advantage for CI wearers; however neither CA (β =- .22, *p* = .26) emotion vocabulary (β = -.25, *p* = .19), non-verbal ability (β = .09, *p* = .63), BSL receptive language (β = -.20, *p* = .28), nor lip-reading (β = .06, *p* = .75), significantly predicted performance. For the hearing group children, there was a significant moderate negative correlation between overall performance and CA (r = -.40, *p* = .04) and emotion vocabulary (r = -.42, *p* = .03); however, a regression analysis (R^2= .30, F = 2.25, MSE = 20.08, *p* = .098) showed that none of these factors significantly predicted performance (*Ps* all > .08).

Heterogeneity of deaf children

Table 8 displays the mean and SDs for the sub-group overall scores in emotion recognition. The possible difference in performance based on the severity of hearing loss was examined comparing the children with a hearing loss classed as moderate-to-severe and profound. Results revealed no significant differences in overall emotion recognition, *t* (25) = -1.12, *p* = .28, Cohen's *d* = .55. Further analysis was performed on the sample of deaf children in order to investigate whether signing ability, preferences in communication style (oral vs. signing), and the type of hearing aid the children had moderated any of the effects reported. For signing ability, deaf children were grouped into those who had signing family members and those who did not. The analysis showed no significant difference in overall errors in emotion recognition between those signing family members than those without, t (28) = 1.61, p =.12, Cohen's d = .71. Preference in communication (oral (N = 21), signing (N = 2) or both (N = 4)) was analysed. As the majority of children in this study preferred to communicate orally, preference for oral communication was compared with the other two types to create a meaningful comparison group. Results revealed that the type of preferred communication did not have a significant effect on emotion recognition, t (25) = -1.16, p = .26, Cohen's d = .56.

Table 8. *Mean and SDs for Overall Emotion Recognition Errors for Subgroups of Deaf Children (Study 2) (Divided by level of deafness, communication preference, and whether have signing family members)*

	Level of deafness		Communication		Signing family Members	
	Severe (N = 21)	Profound (N = 16)	Oral (N = 21)	Sign (N = 6)	Yes (N = 18)	No (N = 9)
Overall score (max. 60)	10.76 (6.54)	7.5 (5.36)	9.29 (6.51)	12.67 (5.43)	11.39 (6.85)	7.33 (4.36)

Note. SDs in parenthesis

Heterogeneity of deaf children: CI vs HA

A possible difference in performance based on the type of hearing amplification was examined by comparing total error scores. Table 9 details the background characteristics of the deaf children with CIs (N = 11) and HAs (N = 16). There were no significant differences between the sub-groups of deaf children in CA, non-verbal ability, language or EVT scores. The deaf children with HAs and deaf children with CIs were compared to the hearing control group children. A one-way ANOVA showed a significant effect of group, F (2, 50) = 5.8, MSE = 28.51, p = .005. Interestingly, further analysis with Bonferroni corrections (adjusted to p <.017) showed that the deaf children with CIs made significantly fewer errors overall than deaf children with HAs, t (25) = 2.62, p =.02; Cohen's d = 1.0; Table 9). The hearing control group children made significantly fewer errors (mean correct = 7.23, SD = 4.91) than deaf children with HAs, t (40) = 3.28, p = .002; Cohen's d = .89; however, there was no significant difference in errors between hearing control group children and deaf children with CIs, t (35) = -.35, p =.73; Cohen's d = .12.

A further series of one-way ANOVAs exploring differences between total error scores for each of the emotions showed no significant difference between groups for Happiness, Sadness, Anger, Fear and Surprise (all ps>.05). Further tests with Bonferroni corrections revealed a significant difference between groups on the emotion disgust, F (2, 50) = 6.97, MSE = 8.02, p =.002). There was no significant difference between CI wearers and either HA wearers, t (25) = .82, p = .42; Cohen's d = .75 (Table 9), or hearing control group children (mean errors = 1.65, SD = 2.26), t (35) = 1.95, p = .062; Cohen's d = .26. However, significantly more errors were made by the children with HAs for disgust than hearing children, t (40) = 4.04, p <.001; Cohen's d = 1.23)

Table 9. *Mean, SDs and Tests of Difference for Deaf children Grouped Based on Hearing Amplification (CI or HA) for Background Information and Errors in Emotion Recognition (Study 2)*

	CI (*N*= 11)	HA (*N* = 16)	*t* (*df* = 25)
Background information			
CA (yrs.mnths)	8.3 (1.4)	8.2 (1.8)	-.15
Non-verbal IQ	89.72 (16.88)	94.44 (17.97)	.69
BSL Receptive	95.1 (8.25)	95.8 (15.48)	.13 (*df* = 23)
Lip-reading	97.27 (23.52)	101.75 (13.99)	.62
EVT	9.82 (2.23)	9.56 (1.71)	-.34
Emotion recognition			
Overall errors (max. 60)	6.55 (6.52)	12.44 (5.15)	2.62*
Disgust (max. 10)	2.45 (3.64)	5.0 (3.1)	.82

Note. SDs are in parenthesis; $*p < .05$

Error patterns

To examine the children's errors, incorrect responses were recorded for each emotion. Cross tabulations were generated in the form of confusion matrices to show the relationship between the actual emotion expression and the emotion label given by participants. Table 10 shows the deaf children's percentage of correct response and errors for each emotion, and Table 11 shows hearing children's percentage of correct response and errors for each emotion.

Table 10.*Cross Tabulations of Actual Emotion Expression (Row) and Expression as Labelled by Deaf children (Columns)*

	Happiness	Sadness	Anger	Fear	Disgust	Surprise
Happiness	**99.33**	0.0	0.0	.00	0.0	0.67
Sadness	0.0	**93.67**	2.67	1.67	1.67	0.0
Anger	0.0	2.67	**93.67**	0.67	3.0	0.0
Fear	1.0	8.0	8.0	**68.67**	8.67	5.67
Disgust	0.0	1.0	38.67	0.33	**60.0**	0.0
Surprise	0.67	0.0	0.0	11.67	0.67	**87.0**

Table 11. *Cross Tabulations of Actual Emotion Expression (Row) and Expression as Labelled by Hearing Children (Columns)*

	Happiness	Sadness	Anger	Fear	Disgust	Surprise
Happiness	**100.0**	0.0	0.0	0.0	0.0	0.0
Sadness	0	**91.03**	0.34	2.41	5.86	0.34
Anger	0.0	2.76	**95.12**	0.69	1.38	0.0
Fear	0.0	3.79	2.76	**62.07**	10.34	21.03
Disgust	0.0	0.69	15.86	0.34	**83.1**	0.0
Surprise	0.34	0.0	0.0	5.17	0.0	**94.48**

Happiness was the most accurately labelled emotion for both groups, and fear and disgust were the least accurate. Disgust proved to be the emotion that caused most difficulty for the deaf children to correctly identify, with 26.1% of deaf children's responses to disgust stimuli being labelled as anger. A similar pattern of results was found for the hearing control group children, as the majority of the errors made in the presentation of disgust stimuli were also incorrectly identified as anger. For the hearing control group children, fear was the emotion most difficult to identify, with 21.03% of responses being labelled as surprise, and 10.34% as disgust. The deaf children followed a different pattern of errors for the emotion, fear, compared to the hearing controls: fear stimuli were most commonly mistaken as disgust followed by sadness and anger, and then surprise. Fewer errors were made for surprise, sadness and anger for both groups. Surprise was most commonly mistaken as fear, and sadness and anger were confused with other negative emotions (disgust, fear, sadness and anger).

Discussion

This is the first study to examine emotion recognition in deaf children using filmed real time video clips of the six basic emotions of human facial expressions. The findings from Study 2 demonstrate that when children have to identify more complex emotions using *real* faces, overall the deaf children performed as well as their controls. The overall findings then suggest that when using more ecological stimuli (dynamic and real faces) deficits are less likely to be found in deaf children's ability to recognise emotions. Interestingly, the deaf children's errors followed a pattern typically found in young children in previous research: happiness followed by anger and sadness, then surprise, fear and disgust (Widen & Russell, 2003).

There was not a main effect of motion, so as predicted in hypothesis one, the dynamic images did not aid the performance of the hearing children. This non-uniform effect of motion is consistent with previous research in typically developing adults (Kamachi et al., 2001; Kätsyri & Sams, 2008) and children (Nelson & Russell, 2011). It has been posited that clear, exaggerated facial expressions posed by human actors are sufficient for identification of basic emotions (Ekman & Friesen, 1978), resulting in near ceiling effects and meaning that dynamic information is unnecessary.

The interaction between motion x participant was significant, indicating that deaf children made more errors than hearing children in the static but not the dynamic presentation as predicted. While the effect size is moderate, these results are suggestive of a role for motion in emotion recognition for deaf children. Emotion is important for deaf individuals in distinguishing between signs (Bosworth & Dobkins, 2002; Corina et al., 2002) and in lip-reading (Haxby et al., 2002), so it seems likely that it would also be important for emotion processing seeing as deaf people are reliant on visual information. These results indicate that with the use of ecologically valid stimuli – dynamic presentations and, crucially, facial expression of emotions in *real* human faces - deaf children are able to identify basic emotions at a similar level to hearing children (Hosie et al., 1998). Further, it is important to consider the effect of motion on deaf children's emotion recognition as the more natural content of the dynamic stimuli not only improves ecological validity, but given the greater activation of brain regions linked to processing of social and emotional information evoked by dynamic relative to those evoked by static images (Klesser et al., 2011; Klits et al., 2013; Krumhuber et al., 2013).

Contrary to hypothesis two but in line with Hosie et al. (1998), the deaf children's performance on the emotion, fear, paralleled that of the hearing children. The deaf children did, however, perform significantly worse than the hearing children in the emotion, disgust; previously shown to be a difficult emotion for children to label (Harrigan, 1984; Markham & Adams, 1992; Michalson & Lewis, 1985; Widen & Russell, 2008a). In examining the pattern of errors it was apparent that disgust was predominantly mistaken for anger, as has typically been revealed in emotion recognition research (Gagnon, Gosselin, Hudon-ven der Buhs, Larocque & Milliard, 2010; Widen & Russell, 2003, 2013). It can be supposed that a greater error rate for deaf children in mistaking disgust for anger could result from being reliant solely on the visual cues in interpreting emotion in the absence of auditory cues; the perceptual similarity of disgust and anger, even though they only share some of the same muscle movements, such as furrowing the brow and raising the upper lip, could account for the confusion (Wilden & Russell, 2008b, 2008c).

It could be argued that the deaf children did not understand the term disgust, yet Widen and Russell (2013) hypothesise, based on a comprehensive review of research, that being able to identify emotion in the facial expression occurs long after initially being able to identify a bad feeling along with other negative emotion concepts (i.e. this situation makes me feel unhappy), followed by linking it to a cause (e.g. something smelling bad), followed by assigning a label (as yucky, disgust or gross). Therefore a concept of disgust needs to be well developed before it can be associated with a facial expression. It would be interesting to further investigate deaf children's understanding of disgust to explore whether they are better at identifying this emotion in the context of a story than in facial expressions.

A further indicator that difference in language and emotion understanding contribute to deaf children's delay in emotion recognition is the significant correlation between scores on the emotion vocabulary and overall errors in emotion recognition. Emotion vocabulary correlated negatively with total number of errors for both hearing and deaf children; however the regression analysis showed that this no longer predicted performance when other factors were taken into account. Feldman-Barrett, Lindquist and Gendron (2007) hypothesise that emotion words that become accessible aid in reducing uncertainty that is intrinsic to most natural facial behaviours and constrain their meaning to allow for rapid and easy perception of emotion. If some deaf children's emotion vocabulary is poorer than that of hearing children it suggests that these emotion concepts are less readily available to be able to rapidly distinguish the disgust face from other expressions.

It is notable that further examination within the deaf group showed a significantly poorer performance in total number of errors made for disgust for those deaf children with HAs compared with CI wearers and hearing children, yet no difference between deaf CI wearers and hearing controls was found. These results are consistent with Hopyan-Misakyan et al. (2009) and Most and Aviner (2009)'s studies showing deaf children with CIs performing parallel to hearing children. Caution needs to be drawn to the interpretation of this difference because of small sample numbers, but the effect size was large. Perhaps the children with CIs have better access to auditory cues of emotion, yet studies with deaf adolescents have shown that current technology does not appear to successfully transmit a speaker's emotional state any better than HAs (Most & Aviner, 2009).

An alternative explanation is that the success of deaf CI wearers in identifying disgust was moderated by their emotion understanding. It is possible that the CI has allowed these deaf children access to the social and linguistic aspects of emotions that occur in everyday life, allowing them to develop the appropriate social and cognitive abilities to facilitate emotion recognition (De Soneville et al., 2002; Most & Aviner, 2009; Peterson & Siegal, 1995). Similarly, some studies involving deaf children with CIs have suggested that their implants have benefited spoken language ability, leading to sufficient exposure to mental state language to enable them to pass theory of mind tasks (Remmel & Peters, 2009; Peters et al., 2009). In the absence of these cues, some deaf children could be missing, or delayed in acquiring, the 'emotion script' that develops by taking clues from their environment and matching it to the facial configuration (Action Unit (AU) 9: the nose wrinkle) of disgust (Widen & Russell, 2008c).

It could alternatively be that this small sample of deaf children with CIs were an exceptional group and not typical of the population of children who receive implants. It could, rather, reflect exposure to language as opposed to a benefit of cochlear implantation per say; for instance, some children for whom implants and oral communication are ineffective may stop using them (Bat-Chava & Deignan, 2001). Studies with larger sample sizes need to examine more precisely the difference between the facial emotion recognition of deaf children with CIs and deaf children with HAs.

Interestingly, Hosie et al. (1998) found an opposing pattern of results as deaf children performed *better* than hearing children in identifying disgust as well as fear. Methodological differences could be accountable. The children partaking in Hosie et al.'s study additionally took part in emotion matching and comprehension tasks that may have improved performance; viewing the full range of facial expressions prior to the labelling task enables comparisons between and within expression types

(Harrigan, 1984; Russell, 1994). Vicari, Reilly, Pasqualetti, Vizzotto and Caltagirone (2000) found that free-labeling "accuracy" improved when a prior task was given. This suggestion is, however, speculative. A difference in pattern of results may not only be accountable to methodological differences but also reflect the heterogeneity of deaf children.

The results of Study 2 reveal that deaf children appear to have a similar conceptual understanding of the basic emotions to hearing children. As well as having a typical pattern in accuracy for each emotion - happiness followed by anger and sadness, then surprise, fear and disgust – the deaf participants also displayed a common pattern of labelling inaccuracies revealing that the errors made are not arbitrary (Widen & Russell, 2003). Like the hearing controls, errors were made by confusing emotions with a similar valence and level of arousal (Bullock & Russell, 1984), for instance disgust was mostly mistaken for anger. The pattern for errors in recognising fear was slightly different between groups. While the hearing children most commonly mistook fear for surprise, both of which are high in arousal, the deaf children mostly confused fear with disgust closely followed by sadness and anger. This may also reflect their relative difficulty in labelling disgust. It is important, though, to emphasise that many studies with adults have shown difficulties in accurately labelling disgust (e.g. Widen & Russell, 2008c).

While the results of Study 1 and 2 are encouraging in terms of deaf children's emotion recognition in real human faces, it is possible that research has still not tested the limit of deaf children's emotion recognition abilities. As per Study 1, near ceiling effects for happiness, sadness, anger and surprise were found, which could mean deaf children's emotion recognition abilities are intact, or that the task was not sufficiently difficult to detect potential differences. Near ceiling results are common in emotion recognition research and have been found in previous studies with deaf children (Most & Aviner, 2009; Ziv et al., 2013). First, a potential criticism is the use of forced-choice distribution which has been shown to result in the highest rates of emotion recognition (Russell, 1994). Arguably, the use of categories affects selection probability and increases the likelihood of randomly selecting the correct answer and using a process of elimination (Wagner, 1997). However, the advantage of a forced-choice method of response is that it is quicker, easier to analyse and reduces the variance found between researchers in terms of what is deemed as a correct response in a free-choice distribution (Russell, 1994). In a recent study, Limbrecht-Ecklundt et al. (2013) found that basic emotions were reliably – i.e. significantly better than occurring randomly – recognised without the choice of answer being specified. One interpretation is that these results are evidence of the universality of emotions and indicate the relevance of basic emotions to interpersonal communication. A further advantage is that it minimises the verbal demands yet still assesses emotion recognition via semantic categorisation (Camras & Allison, 1985) – an important consideration when carrying out research with deaf children.

Second, criticism has been directed at use of prototypical, exaggerated displays of emotion expressions as is commonly utilised in emotion recognition research. While photographs of intense emotion expression have proved to be useful as a tool to study the development of emotion recognition abilities, in everyday life the expressions we perceive are more frequently much less clear-cut, intense and caricature-like (Gao & Maurer, 2010; Manstead, Fischer & Jakobs, 1999; Russell, 1994). Indeed, in a study comparing emotion identification in spontaneous and posed facial expression, recognition accuracy was found to be higher in the posed condition (Motley & Camden, 1988). Comparing emotion recognition at lower levels of intensity has been highlighted as a means of achieving a more sensitive test of emotion recognition abilities in a laboratory setting (Montagne, Kessels, De Haan, & Perrett, 2007).

In this chapter, deaf children were found to parallel hearing children's emotion recognition abilities for all emotions with the exception of disgust. With fewer opportunities to discuss emotions, deaf children may be delayed in developing the emotion 'script' so to link the facial expression to their conceptualisation of the emotion (Widen & Russell, 2008c). Motion was shown to provide an advantage to deaf children's emotion recognition given that overall, dynamic displays were easier to identify than static displays. These findings combined with the findings of Study 1 indicate that real human faces provide an important cue to deaf children's emotion recognition. Largely dependent on the visual domain, motion also provides additional information that a still image cannot. This appears to be redundant for hearing children who recognise emotion through the auditory and visual domain combined. High rates of recognition in some of the emotions in this study with the use of stimuli portraying exaggerated facial expressions may preclude differences that may be revealed with a more sensitive task assessing emotion recognition at varying levels of intensity.

Chapter Five

Study three: the effect of intensity on emotion recognition in deaf children

Overview

In the two prior chapters, deaf children were found to have better rates of emotion recognition with the use of real human faces and with a dynamic as opposed to a static presentation. The study presented in this chapter aimed to further test the limits of deaf children's emotion processing skills by taking into account two additional factors: that in real life, facial expressions can be both subtle and fleeting. Emotion recognition of the six basic emotions was tested in deaf children and hearing controls at a reduced presentation time (500ms) at two levels of intensity: subtle (0-50% of the full expression) and intense (50-100%). Results showed that overall, deaf children's emotion recognition paralleled the hearing control children in demonstrating a significantly higher rate of recognition in the intense than the subtle level of intensity.

Introduction

In chapter four, the importance of acknowledging the dynamic nature of facial expressions was highlighted so to more accurately capture the liveliness and true nature of facial expressions of emotion displayed in day-to-day interactions. Yet an additional consideration is that we frequently experience briefer, more subtle and less intense changes in emotion facial expressions in everyday life than are commonly displayed in the prototypical, exaggerated images used in emotion recognition research (Gao & Maurer, 2010; Manstead et al., 1999; Russell, 1994).

When presented with prototypical expressions of high intensity, typically developing children are able to identify emotions with a great improvement in accuracy when matching or labelling by aged three to seven years (Carmas & Allison, 1985; Durand et al., 2007). For instance, Durand et al. (2007) found that children as young as five or six were able to recognise sadness and happiness at adult level, and by around 10 years of age, children could also recognise fear and anger, and by around 11 years of age they could recognise disgust at a parallel level to adults. Thomas and colleagues highlight that the anatomic and functional changes that occur during late childhood and adolescence are in conflict with behaviour studies that suggest emotion recognition reaches adult levels by late childhood, arguing that maturity of emotion recognition abilities may not be reached until adulthood (Thomas, De Bellis, Graham & LaBar, 2007). The amygdala, for example, most associated with being activated by fearful responses, has been shown to develop through to late adolescence (e.g. Schumann et al., 2004). It has been suggested that emotion recognition research may be prone to ceiling effects given that many studies use prototypical category exemplars of emotion that are not sensitive to nuances of emotion facial expressions of a lesser intensity (Thomas et al., 2007).

When increased processing demands are taken into account, emotion recognition has been shown to continue to develop throughout adolescence in typically developing children (De Sonneville, et al., 2002; Thomas et al., 2007). De Sonneville et al. emphasised the importance of considering speed of processing given that facial expressions may change rapidly and low processing may hamper communication in everyday life. It was found that accuracy did not improve considerably between the ages of seven and ten, but processing speed significantly improved. Moreover, the adults were markedly faster and more accurate than the children.

Intensity has also been shown to mediate accuracy in typically developing children's identification of emotion expressions (Gao & Maurer, 2010; Herba et al., 2006; Montirosso et al., 2010). In this context, intensity can be defined as the relative degree of movement away from a neutral expression of muscles that are activated in a particular facial expression of emotion (Hess, Blairy & Kleck, 1997). The intensity of the emotion facial expression of happiness, for example, can be signified by the extent of identifiable activity in the Zygomaticus Major and Orbicularis Oculi muscles, moving away from their relaxed states (Ekman & O'Sullivan, 1991).

Children only a few months old have been shown to be able to distinguish happy and sad faces from surprise faces, and to differentiate between faces of mild and intense happy expressions (Nelson & De Haan, 1997). Yet with the exception of happiness, a slower development over age to the detection of all other basic emotions has been revealed. Only a handful of studies have conducted tasks investigating typically developing children's labelling of all six of the basic emotions at varying intensity using dynamic human faces. Montirosso et al. (2010) used a morphing technique to display facial emotion expressions at four levels of intensity (35, 50, 75 and 100 per cent). Children were shown to develop with age at recognition accuracy of all emotions except disgust, and accuracy was shown to increase as a function of intensity. Gao and Maurer (2010), using 20 levels of intensity, similarly found slower development for all emotions except happiness, with recognition increasing as intensity of expression increased. It is supposed that because intense affective facial expressions have larger movements, it generally makes them easier to recognise (Law Smith, Montagne, Perrett, Gill & Gallagher, 2010).

In other clinical populations proposed to have emotion processing difficulties, such as children with autism, a higher level of intensity has been shown to be required for correct identification in comparison to control group children (Law Smith et al., 2010; Rump, Giovannelli, Minshew & Strauss, 2009). Law Smith et al. (2010) used a morphing video task to test emotion recognition at increasing levels of intensity in adolescents with high-functioning autism. Subtle differences were found: anger and surprise were shown to be impaired at lower levels of intensity and disgust was most impaired, even at 100% intensity level and lower. Whereas, in comparison a number of prior studies utilising full blown prototypical faces found no group difference (e.g. Grossman et al., 2000), suggesting possible ceiling effects. Rump et al. (2009) similarly found that both children and adults performed significantly worse when comparing emotion recognition abilities as a function of intensity using video clips of filmed real time human expressions. This suggests that testing emotion recognition at different levels of intensity may be an effective way of identifying atypical patterns in emotion processing.

The majority of studies investigating emotion recognition in deaf children have utilised stimuli displaying prototypical, or relatively intense, expressions of all (or some) of the six basic facial expressions of emotion (Hosie et al., 1998; Ludlow et al., 2010; Ziv et al., 2013). Hosie et al. (1998) used Ekman and Friesen's (1976) standardised set of Pictures of Facial Affect, containing photographs of exaggerated facial expressions at 100% intensity, and found no differences between the deaf and hearing group. It is questionable as to whether this stimulus was too simplistic to represent emotion recognition that occurs in everyday life. Ziv et al. (2013) likewise found that deaf children with CIs and signing deaf children performed similarly on an emotion recognition task requiring labelling photographs of children. Hopyan-Misakyan, et al., (2009) used two levels of intensity when assessing deaf children aged between 7 and 12 on visual emotion recognition (in addition to speech perception and affect speech prosody) and found that their performance paralleled that of hearing children. Yet the images utilised were static and only four of the emotions - happiness, sadness, anger and fear - were included. On the other hand, Wiefferink et al. (2013) and Ludlow et al. (2012) found a deficit in deaf children's emotion recognition, yet the stimuli utilised included cartoons. It has been argued that the use of schematic stimuli is oversimplified in comparison to real actors portraying validated facial expressions (Williams et al., 2007) as they do not contain the nuances of human facial features and temporal dynamics that better reflect day-to-day emotion interactions.

Most and Michaelis (2012) tested young deaf children (aged 4 to 6) using the Emotion Identification Test (EIT), in which an actress portrayed each expression (anger, fear, sadness and happiness) while uttering a nonsense sentence, providing a more life-like depiction. The task compared deaf and hearing children in three different modes – auditory, visual and auditory-visual combined. The deaf children performed significantly worse in all three conditions. Most and Aviner (2009) compared deaf and hearing children (aged between 10 and 17 years) using the EIT plus two additional emotions, disgust and surprise. While the hearing children performed better in the auditory and combined conditions, the groups performed similarly in the visual condition. Yet the results exhibited near ceiling effects as have other studies investigating emotion recognition in deaf children (e.g. Ziv et al., 2013; Study 2). In addition, in the majority of studies the children were allowed as long as they needed to respond, which may not reflect the processing demands of day-to-day life (De Sonneville, et al., 2002).

An exception is Dyck et al.'s (2004) study, which tested deaf children's emotion recognition with the Fluid Emotions Test (FET) containing morphed images of emotion expressions. While allowing up to four seconds' identification time, the FET scores were based on both accuracy and response time; the deaf children were shown to be poorer relative to hearing controls. As aforementioned, however, the deaf children in Dyck et al's study had a mean average IQ that was two standard deviations below the deaf national average and the effect was also moderated by verbal ability. Further, morphed facial expressions are lower in ecological validity than real, dynamic human faces in emotion recognition measurement. It remains a possibility that the limit of high functioning deaf children's emotion recognition abilities has not been tested.

The role of intensity in facial emotion recognition in deaf children could reveal important information about their emotion processing abilities. To reiterate, one possible explanation for deaf children's lower performance in some emotion recognition tasks is that the spoken language context is important in accompanying visual emotional information when developing the ability to perceive emotions. Deaf children in a hearing environment are not exposed to the rich environment of a natural language and have reduced opportunities to overhear conversations revolving around emotion and mental-state talk. If late-signing deaf and oral deaf children exhibit difficulties in ToM (e.g. Peterson & Siegal, 1995), it is possible they may have difficulties in interpreting emotions of lower intensities. It is plausible that improvements in cognitive skills, such as perspective taking, could aid the development of understanding the meaning of subtle emotion expressions (Choudhury, Blakemore, & Charman, 2006).

Deaf children's experience of non-verbal communication may be indicative of how they may respond to level of expressiveness as measured by intensity. A study by Goldstein, Sexton and Feldman (2000) found that hearing signers were more accurate at conveying emotion expressions than non-signing hearing adults; it could be that deaf children are more habituated to animated expressions when communicating emotion due to experience with sign language. Hearing children, on the other hand, may have become accustomed to interpreting subtle cues from emotion facial expressions alongside auditory ones that may be more challenging for deaf children. Alternatively, if the pattern of emotion recognition displayed by the deaf children parallels that of the hearing children it is more likely that human faces are of particular importance and sufficient to enable emotion recognition for deaf children.

Study 3

The primary aim of this current study was to explore the effects of intensity and reduced display time on deaf children's emotion recognition ability to achieve a more comprehensive understanding of the extent of their abilities. The deaf children's facial emotion recognition of the six basic emotions – happiness, sadness, anger, fear, disgust and surprise - was examined with the use of brief (500 ms) dynamic clips of real human videoed expressions at varying degrees of intensity. To our knowledge, Rump et al.'s (2009) study was the first to use filmed clips of real human faces to measure the effect of intensity on emotion recognition. In the present study, an edited version of the ADFES (Van der Schalk, et al., 2011) was created. The ADFES is unique in that it is the only standardised set of natural filmed expressions, which clearly has an advantage in ecological validity over the morphing technique that is traditionally employed. In addition, previous research has shown that movement facilitates recognition at low intensities (Ambadar et al., 2005). The selected video clips were edited into four levels of increasing intensity (level one: 0-25%; level two: 25-50%; level three: 50-75%; level four: 75-100%) in a similar way to Rump et al.'s (2009) development of experimental stimuli to investigate the impact of intensity emotion recognition in individuals with autism.

A number of hypotheses were explored based on previous research. Primarily, the aim was to compare the performance of deaf children's facial emotion recognition to that of hearing children. Due to the paucity and variance in methodological approaches taken in deaf children's emotion recognition research (a number of which exhibited near ceiling effects as were also found in Study 2 e.g. Most & Aviner, 2009; Ziv, et al., 2013) it was difficult to make a specific prediction. However, based on the theory that deaf children have difficulty in emotion recognition due to reliance on the visual mode, it was predicted that they would perform worse at the more challenging task of identifying the negative emotions (sadness, fear and disgust) of low intensity. In particular it was predicted that the deaf children would at least show poorer performance in the identification of the emotion, disgust, given the increased task demands in this present study. Second, it was predicted that performance of all children would improve with increased levels of intensity. Third, it was expected that performance would positively correlate with age, in particular for the hearing children in line with previous studies (Herba et al., 2008; Montirosso et al., 2010).

Method

Participants

Twenty-eight deaf children (15 male) took part in this study aged between 6 years 11 months and 12 years 1 month (mean CA = 9 years 3 months; *SD* = 1 year 6 months) . All participants fulfilled the criteria of a sustained pre-lingual hearing loss of either “moderate-severe” (hearing loss > 60 db; *N* = 15) or “profound” (hearing loss > 90 db; *N* =13). The children all attended one of six schools with an attached specialist hearing unit and were educated with a mixture of an oral approach and the use of BSL and/or SSE. The majority of children were oral in their communication preference (*N* = 20). Only two deaf children communicated mainly in BSL and six used a combination of oral and BSL. Despite the majority being largely oral, most of them used some sign language. All children received auditory amplification: 15 children wore cochlear implants (CI) and 13 wore hearing aids (HA). None of the children had any identified additional learning difficulties in addition to their deafness.

A group of 28 control children with no hearing loss matched for CA and gender (15 male), aged between 6 years 9 months and 11 years 6 months (mean CA = 9 years 3 months; *SD* = 1 year 8 months), also partook in the study. Table 12 displays CA, non-verbal IQ scores and language scores for deaf and hearing control children. Independent t-tests confirmed that the groups were well matched on non-verbal ability (t (54) = -1.17, p = .25) as well as CA (t (54) = -.03, p = .99).

Table 12. *CA, Non-Verbal IQ and Language Measure Mean Scores and SDs for Deaf and Control Group Children (Study 3)*

	Children	
	Deaf (*N* = 28)	Control(*N* = 28)
CA (yrs. mnths)	9.3 (1.6)	9.3 (1.8)
IQ Standard	93.79 (14.7)	98.21 (13.69)
BPVS standard		96.04 (12.42)
Lip Reading	99.04 (15.04)	
BSL Receptive	94.17 (14.91) (*N = 23)*	

Note: Standard deviations are in parenthesis.

Materials

To create the experimental stimuli, dynamic clips of human faces were selected from the ADFES (Van der Schalk et al., 2011). The ADFES is a standardized set of video clips of North-European people based upon the prototypes of the 'basic emotions' according to the FACS guide (Ekman et al., 2003). Three sets of videos clips of the six basic emotions - happiness, sadness, anger, disgust, fear and surprise – portrayed by four of the actors were selected. For two of the actors (one male), each of the six basic emotions were used. For a further two actors, three of the emotions - happiness, sadness and anger – were selected from one actor (male); and the other three emotions - fear, disgust and surprise - were selected from the other (female), to ensure a balance of gender in the experimental stimuli (Table 13). Carefully examining the selected videos frame-by-frame, they were edited into clips by dividing them into four levels of emotion intensity: 0-25%, 25-50%, 50-75% and 75-100%, using the software, VirtualDub (VirtualDub.org). In total, 72 dynamic video clips were created, each lasting 500ms: three sets of the six basic emotions at four levels of intensity. The static endpoints for each of these stimuli can be seen in Appendix C.

Table 13. *Dynamic Video Clips of Emotion Selected from ADFES (Van de Schalk et al., 2011) to be edited in Intensity*

	Emotion Video Clips
Male 11	Happiness, Sadness, Anger, Fear, Disgust, Surprise
Male 12	Happiness, Sadness, Anger
Female 5	Happiness, Sadness, Anger, Fear, Disgust, Surprise
Female 1	Fear, Disgust, Surprise

Pilot of Emotion Intensity Stimuli: The set of video clips was piloted on university undergraduate students (N = 29; 22 female; mean CA = 23 years 8 months, SD = 7 years 6 months). To begin each video clip, participants were requested to press ‘play’. After each clip was presented, the six emotion words – happiness, sadness, anger, fear, disgust and surprise – appeared on the screen. Participants were asked to identify the emotion by clicking on the relevant emotion word, and also to rate the intensity of the clip on a scale of 1-5: 1- not at all intense; 2- a bit intense; 3- mildly intense; 4- very intense; 5- extremely intense. The clips were presented in a random order. Findings of the pilot study showed that most participants were accurately able to identify all emotions by the 50-75% level;

ratings of intensity increased accordingly with each increasing level of intensity. See Appendix D for accuracy percentages and intensity ratings.

Design

The study used a mixed-factor design, with one between subject factor (Group) with two levels (deaf vs. controls) and two within-subjects factors: Emotion, with six levels (happiness, sadness, anger, disgust, fear, surprise); and Intensity, with two levels (the original four levels were combined into two intensity levels: subtle 0-50% and intense 50-100%). The order of the video clips was randomised. Results were analysed using a mixed factorial ANOVA.

Procedure

To ensure the children understood the emotion terms, they were initially shown a photograph of each of the six basic emotions and asked to label each one (*"how does he/she feel?"*) and to give an example of when the emotion may be experienced (e.g. Experimenter: *"when do you feel sad?"* Child: *"I feel sad when I have nobody to play with"*). Three deaf children were excluded because they were unable to answer the control questions. Each child sat 60 cm in front of a 14-inch portable computer on which the video clips were presented. Instructions were given verbally or signed, explaining to the child that the task involved watching video clips of actors pulling facial expressions of emotion and they needed to tell the experimenter whether the face showed happiness, sadness, anger, fear, disgust or surprise.

As per the pilot study, each video clip was started by pressing 'play' once the child was attending. Each clip appeared on the screen for 500ms and then disappeared, followed by the emotion words appearing on the screen in a randomised order (anger, surprise, sadness, disgust, fear, happiness). After watching the video clip, the child needed to select the emotion by telling the experimenter/clicking on the appropriate emotion word. Older children clicking on the emotion word independently were asked to simultaneously say aloud, or sign, the emotion word, to ensure reading errors were not made. Breaks between trials were taken if necessary. The procedure took approximately 15 minutes.

Results

Accuracy

Table 14 displays the mean and standard deviation scores for each Emotion (happiness, sadness, anger, disgust, fear, and surprise) and level of Intensity (subtle vs intense) for deaf and control group participants. Analysis revealed that there was no significant main effect of Group, F (1, 54) = .46, MSE = 2.52, p = .50, η^2 = .01, suggesting that overall, deaf children's performance on emotion recognition was not significantly different from that of the hearing control children. As expected, there was a main effect of Intensity, F (1, 54) = 943.77, MSE = 1.19, p < .001, η^2 = .95, meaning that more subtle displays of emotion were significantly more difficult to recognise than more intense displays.

Table 14. *Mean and SD of Errors in Identifying Emotions by Intensity and Group (Maximum Error of 6 per Emotion and Level of Intensity)*

	Deaf		Hearing	
	Subtle	Intense	Subtle	Intense
Happiness	2.43 (1.29)	.04 (.19)	2.21 (1.37)	.04 (.19)
Sadness	2.68 (1.68)	1.04 (1.14)	2.68 (1.36)	1.46 (1.07)
Anger	4.21 (.74)	.32 (.72)	4.04 (1.1)	.85 (1.15)
Disgust	4.21 (1.45)	2.04 (2.3)	3.46 (1.37)	1.21 (1.45)
Fear	5.25 (.93)	2.36 (1.45)	5.18 (1.19)	2.71 (1.61)
Surprise	3.89 (1.23)	.57 (1.43)	3.82 (1.02)	.36 (.91)

Note: Standard deviations are in parenthesis

There was also a main effect of Emotion, F (5, 270) = 50.68, MSE = 1.78, p <.001, η^2 = .48, showing that some emotion expressions were more easily identified than others. Most accurately identified was happiness, followed by sadness, surprise, anger, disgust and then fear. Post hoc tests with Bonferroni corrections (adjusted to p <.003) showed that happiness was significantly more easily recognised than any other emotion and fear was significantly less accurately recognised than any other expression (Table 15).

The results revealed a significant interaction between Intensity and Emotion, F (5, 270), = 13.48, MSE = 1.3, p <.001, η^2 = .20. The intense displays of sadness were significantly more easily recognised than fear, but more difficult to recognise than happiness, anger and surprise. However, in the subtle display of emotion sadness was significantly easier to recognise than all emotions except happiness (p<.001).

Table 15. *Mean Differences between Emotions and Significance Levels (Bonferroni Corrected) (Emotion Intensity, Study 3)*

Emotion	Anger	Disgust	Fear	Happiness	Sadness	Surprise
Anger						
Disgust	-.373					
Fear	-1.518***	-1.143***				
Happiness	1.179***	1.554***	2.696***			
Sadness	.393	.768	1.911***	-.786***		
Surprise	.196	.571	1.714***	-.982***	-.196	

*** p <.001

A marginally significant interaction of Emotion and Group was found, F (5, 270) = 2.22, MSE = 1.78, p = .052, η² = .04. Further analysis with Bonferroni corrections (adjusted to p <.008) displayed a similar profile to hearing children for happiness, sadness, anger, fear and surprise (*Ps* all >.34); the hearing children's performance in labelling disgust showed a trend of being superior to deaf children's, but with Bonferroni corrections this was not significant (t (54) = 2.05, p = .05, ns; Cohen's d = .55). The interaction of Intensity and Group (F (1, 54) = 2.41, MSE = 1.19, p =.13, η² = .04) and the three way interaction between Intensity, Emotion and Group, F (1, 270) =.58, MSE = 1.3, p =.72, η² = .04, were not significant, meaning the groups' overall performance was similar at both levels of intensity.

Factors predicting performance

Further analysis was conducted to investigate the relationship between CA, non-verbal IQ, verbal ability (BSL for deaf children and BPVS for hearing children), and subtle and intense emotion total error scores for both groups. For the deaf children, lip-reading and type of hearing amplification (coded as 0 = CI, 1 = HA) were additionally added as predictors (mean scores, see Table 16). A regression analysis revealed that for deaf children's total intense emotion error scores (R^2= .34, F = 1.72, MSE = 11.0, p = .185), type of hearing amplification (β = 3.26, p = .04) significantly predicted performance, but not CA (β = -.07, p = .18), non-verbal IQ (β = .03, p = .52), lip-reading (β = .05, p = .31), or BSL scores (β = .06, p = .36). This suggests an advantage for those with a CI over HA wearers in performance on the intense emotion stimuli. For deaf children's total subtle emotion error scores, none of the factors significantly predicted performance (R^2= .16, F = .64, MSE = 12.35, p = .68).

For hearing children, a regression analysis for total intense emotion error scores (R^2= .34, F = 4.13, MSE = 6.77, p = .02), CA (β =-.08, p = .009) and verbal ability (BPVS) (β = -.26, p = .02) but not non-verbal ability (β = .08, p = .09), significantly predicted performance, suggesting an improvement in emotion recognition with CA and with a higher verbal ability. A regression analysis for hearing children's total subtle emotion error scores followed the same pattern for CA (R^2= .21, F = 2.08, MSE = 11.13, p = .13): CA predicted performance (β = -.08, p = .04), but verbal ability (BPVS) did not (β = -.12, p = .09). Non-verbal ability was also not a predictor of performance (β = .005, p = .93).

Heterogeneity of deaf children

Potential differences within the deaf group were investigated in terms of a total number of both intense and subtle errors made. The mean and SDs of total intense and subtle errors made for each subgroup are shown in Table 16. Level of deafness was explored by comparing moderate-severely deaf to profoundly deaf children; no significant difference was found in total number of either intense emotion errors, *t* (26) = -1.57, *p* = .13, Cohen's *d* =.60*;* or subtle emotion errors, *t* (26) = -.42, *p* = .68, Cohen's *d* = .16. Preference in communication (oral (*N* = 20), signing (*N* = 2) or both (*N* = 6)) was analysed. As the majority of children in this study preferred to communicate orally, preference for oral communication was compared with the other two types to create a meaningful comparison group. Results revealed that the type of preferred communication did not have an effect on intense, *t* (26) = .72, *p* = .48, Cohen's *d* = .30; or subtle emotion recognition errors, *t* (26) = -.31, *p* = .76, Cohen's *d* = .13. A further exploration involved grouping children according to whether or not parents signed at home (the majority of those with signing family members had either basic or Level 1 BSL; three signed at Level 2 and one at Level 3 BSL). No significant difference was found between children with signing family members and those without for either number of intense emotion errors, *t* (26) = -2.09, *p* = .84, Cohen's *d* = .08; or number of subtle emotion errors made, *t* (26) = .013, p = .990, Cohen's *d* =.002.

Table 16. *Mean and SDs for Total Subtle and Intense Emotion Recognition Errors for Subgroups of Deaf Children (Study 3) (Divided by hearing amplification, level of deafness, communication preference, and whether have signing family members)*

Emotion error (max. 36)	CI or HA		Level of deafness		Communication		Signing family members	
	CI (N = 15)	HA (N= 13)	Severe (N = 15)	Profound (N = 13)	Oral (N = 20)	Sign (N = 8)	Yes (N = 19)	No (N = 9)
Subtle	22.1 (3.0)	23.31 (3.82)	22.93 (3.79)	22.38 (2.99)	22.55 (3.39)	23.0 (3.59)	22.68 (3.2)	22.67 (3.97)
Intense	5.07 (2.4)	7.85 (3.83)	7.23 (3.86)	5.31 (2.5)	6.65 (3.44)	5.62 (3.38)	6.26 (3.31)	6.56 (3.75)

Note: Standard deviations are in parenthesis.

Type of hearing amplification (CI vs. HA)

As deaf children with a CI (N = 15) appeared to potentially exhibit an advantage over children with a HA (N = 13), further exploration comparing the three groups of children (Hearing vs. CI vs. HA) on each emotion separately was carried out. Table 17 displays the mean and SDs of the background characteristics of deaf children with CIs or HAs. There were no significant differences between the sub-groups of deaf children in CA, non-verbal ability, or language scores.

A one-way ANOVA exploring differences between total error scores for each of the emotions (maximum 12) showed no significant difference between the three groups of children for Happiness, Sadness, Anger, Fear and Surprise (all *ps*>.08). There was a significant difference between groups on the emotion disgust, F (2, 53) = 6.66, MSE = 7.24, p = .003). Further comparisons with Bonferroni corrections (significance level adjusted to p <.02) showed significantly more errors were made by the children with HAs for disgust than deaf children with CIs, t (26) = 2.58, p = .02, Cohen's d = .98 (Table 17), and hearing control group children (mean error = 4.68, SD = 2.29; t (39) = 3.67, p = .001, Cohen's d = 1.16). There was no significant differences between the deaf children with CIs and hearing control children (t (41) = .23, p = .82, Cohen's d = .07).

Table 17. *Mean, SDs and Tests of Difference for Deaf Children Grouped Based on Hearing Amplification (CI or HA) for Background Information and Errors in Recognition of Disgust (Study 3)*

	CI (*N*= 13)	HA (*N* = 15)	*t* (*df* = 26)
Background information			
CA (yrs.mnths)	9.1 (1.6)	9.5 (1.7)	-.66
Non-verbal IQ	92.0 (13.47)	95.85 (16.31)	-.68
BSL Receptive	93.82 (12.6)	94.5 (17.33)	-.11 (*df* = 21)
Lip-reading	98.87 (14.46)	99.23 (16.27)	-.06
Emotion recognition			
Disgust (max. 12)	4.87 (3.0)	7.85 (3.1)	2.58*

Note. SDs are in parenthesis; *p <.05

Discussion

In previous studies it was possible that the use of prototypical, exaggerated facial expressions, and an unlimited amount of time to view experimental stimuli, did not test the limit of deaf children's ability in facial emotion identification (Hosie et al., 1998; Most & Aviner, 2009; Ziv et al., 2013). This study aimed to provide a more life-like test of emotion recognition in deaf children, by using dynamic real faces, presented briefly and with subtle expressions. The results did not provide support for hypothesis one: as per Study 2, the deaf children did not have an overall deficit in facial emotion recognition in comparison to hearing controls, even on a task placing higher demand on processing skills. The deaf children showed a similar pattern of errors as the hearing children in finding fear the most difficult emotion to recognise and happiness the easiest.

The deaf children's error profile also closely matched that of the hearing control group children in demonstrating a greater difficulty in recognising more subtle in comparison to more intense emotions, as predicted by hypothesis two. These findings are consistent with previous studies investigating the impact of emotion intensity on recognition rates of typically developing children (Gao & Maurer, 2010; Herba et al., 2006; Montirosso et al., 2010). It has been supposed that poorer recognition at lower levels of intensity may be due to less clear expression of some of the features that make emotion expressions distinct enough from one another to enable effective encoding (Montirosso et al., 2010). De Sonneville et al. (2002) reasoned that the process for distinguishing between similar features requires great effort and controlled information processing, and so is likely to make use of a featural processing strategy. In which case, a low intensity dynamic display does not afford the clear configural information that is usually provided by motion (Ambadar et al., 2005). Therefore, this 'piecemeal' approach to processing emotion requires each feature to be managed separately in a rapid amount of time (Montirosso et al., 2010).

Alternatively, being able to correctly identify subtle facial expressions of emotion may indicate that an individual is better at making subtle configural discriminations (Rump et al., 2009). Configural processing has been defined as the ability to detect the spatial distances or relationships between features of the face rather than directing attention to single non-spatial features such as the nose (Maurer, Le Grand & Mondloch, 2002). When facial expressions are exaggerated, the degree of spatial movement from a neutral expression is much greater making emotion expressions easier to detect. To be able to identify subtle expressions, therefore, an individual is required to detect small motoric spatial differences in muscles (Rump et al., 2009). Either of these theories provides an explanation as to why happiness is not so greatly affected by intensity of expression, as was found in the present study and in previous research, because happiness is shown to be recognisable through the mouth (i.e. the smile) alone. On the other hand, fear is particularly difficult to discriminate from surprise in the eye region due to subtle differences in eye movement (Ekman, 2003, 2007).

Yet while a more featural processing strategy or more sophisticated configural processing may be required at lower levels of intensity, motion has been shown to improve recognition for subtle displays of emotion in comparison to static images (Ambadar et al., 2005). There may be a potential confounding effect between motion and intensity given that both have been shown to facilitate emotion recognition (Montirosso et al., 2010). In Study 2, deaf children were found to show comparable performance to hearing children on dynamic human facial expressions, but were poorer at recognising static faces. This suggested that deaf children are particularly responsive to socially valid stimuli and are more dependent on motion cues and the features of real human facial expressions. As deaf children were shown to perform worse at recognition of intense static stimuli, this effect may be more pronounced in static subtle human faces. This could be clarified by comparing the perception of static and dynamic images of increasing intensity (Ambadar et al., 2005). Regardless, the results of the present study also indicate that deaf children's emotion recognition parallels that of hearing children with the use of video clips of real human faces, even when viewing the more subtle, fleeting expressions of emotion more commonly experienced in everyday life.

As predicted, the performance of the hearing children for recognition of subtle facial expressions of emotion improved significantly with age, which is consistent with previous research with typically developing children (Gao & Maurer, 2009; Herba et al., 2006; Montirosso et al., 2010). As children get older they become increasingly more sophisticated at being able to detect the slight spatial differences between features caused by minute muscular movements that are typical of subtle facial expressions of emotion. The recognition of intense facial expressions of emotion was also shown to improve significantly with age for the hearing children. There is also evidence that with age, typically developed children become better at categorising emotions, particularly the comparatively more difficult negative emotions of fear and disgust (Widen & Russell, 2008b). Attributed reasons include the relative complexity and socialisation factors leading to an improved concept of these emotions (Montirosso et al., 2010; Widen & Russell, 2003). Interestingly, for the deaf children age was not a significant predictor of recognition of either subtle or intense facial expressions of emotion. Only hearing amplification (an advantage for CI wearers over HA wearers) predicted performance in recognising intense emotion expressions. According to the theory that emotion understanding occurs through a process of socialisation, some deaf children may have better social and language access to relate experience of emotional events to prototypical facial expressions (Widen & Russell, 2003). This theory needs confirmation through further studies exploring more explicitly differences in emotion understanding and perception between deaf children with HAs and CIs.

It is noteworthy, however, that in line with the results of Study 2 the deaf children showed a trend of making more errors in recognising disgust than hearing control children. While this was not statistically significant, the children with HAs were shown to perform significantly worse at recognising disgust than hearing children and deaf children with CIs, as per Study 2. One plausible explanation is, because deaf children are more reliant on visual cues when recognising emotion, disgust is more easily confused with anger: an emotion that is similar in terms of negative valence and arousal. In the absence of auditory cues, perhaps some deaf children are delayed in acquiring the ‘emotional script’ that accompanies disgust, which allows interpretation of environmental cues enabling them to distinguish disgust from anger (Widen & Russell, 2008b). It is possible that the children with CIs have more access to the social and linguistic aspects of emotions to enable them to perform on a par with hearing children.

Verbal ability was also found to predict the performance of hearing children in recognising intense facial expressions of emotion, as has previously been shown in a few studies that have considered language when investigating typically developed children’s emotion recognition (Beck, Kumschick, Eid & Klann-Delius, 2012; Ruffman, Slade, Rowlandson, Rumsey & Garnham, 2003). In a recent study, Beck et al. (2012) found receptive vocabulary to predict typically developing children’s emotion knowledge, including emotion recognition. Beck et al. reasoned that this link highlights that a wide and varied vocabulary suggests that large parts of the conceptual system is verbally encoded, including emotion conceptualisation. Emotion recognition and verbal ability may be interrelated as both are dependent on learning and categorising via experience. Feldman-Barrett et al. (2007) argue that a well-developed vocabulary means that emotion concepts are more readily available for emotion categorisation.

No such relationship was found in the deaf group of children. It is possible that the language measures utilised for the deaf children in this study may not have sufficiently tapped into their linguistic abilities, or alternatively that other unexplored factors mediated performance. While the deaf children were all using SSE, none of the children used sign language (BSL) as their main communication method. A lack of standardised language measures for deaf oral populations makes exploring language abilities in deaf children challenging (Prezbindowski & Lederberg, 2003). Future studies should focus on developing language measures standardised for deaf populations and exploring the relationship between deaf children's emotion understanding and language.

It is not trivial that deaf children broadly parallel hearing children on their performance in this study. While deaf children may be more reliant on human facial features (Ludlow et al. 2010; Studies 1 and 2), they appear to be no more at a disadvantage than hearing children at the more challenging task of detecting emotion in subtle displays. These results are consistent with several other studies suggesting that emotion recognition in deaf children is comparable to hearing children's when assessment involves the use of static pictures (Hopyan-Misakyan et al., 2009; Hosie et al., 1998; Ziv et al., 2013) or video clips (Most & Aviner, 2009) of real human faces. However, Dyck et al.'s (2004) study with the more challenging processing demand of measuring speed of response as well as accuracy, found opposing results. Yet Dyck et al. found that the difference between deaf and hearing groups was no longer found to be significant when language ability was taken into account, and the task included the additionally more complex emotion of contempt.

Several researchers have theorised that the early basic social-perceptual skills and knowledge, including emotion recognition, underpins the later development of a social-cognitive ToM, as measured by the false belief task (Baron-Cohen et al., 1993; Hobson, 1991, 1993). This idea has been used to explain how individuals with ASD have difficulties in processing more belief based emotions such as surprise

(Baron-Cohen, Spitz & Cross, 1993) and difficulty with less intense displays of emotion (Law Smith et al., 2010). Yet while deaf children have shown significant delays in performance on the false belief task, no such delays have been found in recognising the emotion, surprise. Neither was a delay shown in recognising subtle emotion expressions relative to the hearing control group children as might have been expected, given that cognitive skills in perspective taking may be related to understanding the meaning of subtle emotion expressions (Choudhury et al., 2006).

Language ability has been found to relate to deaf children's difficulty in performing on the false-belief task (Schick et al., 2007), including the theory that this relates to having fewer opportunities to discuss emotion (Peterson et al., 1995). Potential difficulty in recognising the emotion, disgust, may also reflect that because deaf children have reduced opportunities to overhear conversations with emotional content, meaning a full understanding of this more complex emotion develops later in deaf children. It should be acknowledged that only a subset of video clips from the ADFES (Van der Schalk et al., 2011) were selected to render the clips into varying levels of intensity. For pragmatic reasons, it can only be expected that a limited number of experimental stimuli can be presented to children. Further exploration of emotion recognition abilities could be carried out by creating more subtle stimuli with the entire ADFES, including the investigation of more complex emotions, such as contempt, and the self-conscious emotions contained in the stimuli set (i.e. embarrassment, pride).

The present study shows that deaf children's overall performance on an emotion recognition task examining the ability to identify the six basic emotions was on a par with hearing children. This study was unique in that it utilised standardised video clips of real human faces and considered the added process demands of a reduced display time and varying degrees of intensity. The evidence suggests that deaf children's processing style is very similar to that of hearing children, indicating that deaf children do not have a perceptual difficulty. Rather, a problem with recognising the emotion, disgust, is indicative of the role of language in emotion understanding (Feldman-Barrett, 2009; Widen & Russell, 2003). Future studies should consider the development of the recognition and understanding of more complex, social emotions (i.e. pride, guilt and embarrassment), including development into adulthood.

Chapter Six

Study Four: Emotion production of deaf children

Overview

Studies 1 to 3 addressed deaf children born to hearing parents' emotion recognition abilities. This chapter attends to a novel aspect of deaf children's emotion processing: the ability to voluntarily encode facial expressions of emotion. The encoding of the six basic emotions was elicited by three methods: verbal labels, emotion production in the context of signed stories, and the imitation of emotion expressions of dynamic human faces. Overall, the results showed that the deaf children were able to produce *more* accurate expressions of emotion than hearing children in the first two conditions and were rated with similar levels of accuracy in the imitation condition. The exception was that deaf children were significantly worse than hearing children at encoding disgust in the verbal label and imitation conditions, in line with the emotion recognition studies. Deaf children were also rated as being more expressive in all conditions, suggesting a high level of expressiveness may be important to their display rules. These results strongly implicate the process of socialisation in emotion understanding and expression.

Introduction

It is well established that deaf children of hearing parents have difficulty in understanding others' false beliefs suggesting a delay in the development of Theory of Mind (ToM) (e.g. Peterson & Siegal, 1995, 1999). While deaf children's delay in language acquisition is strongly suggestive of a role of language in understanding others' intentions and emotions (e.g. Schick et al., 2007), far less consideration has been given to early social communication that has been implicated in ToM development (e.g. imitation, mental state information gleaned from faces and voices). Several theorists have argued that more complex social-cognitive abilities are underpinned by a foundation of basic social-perceptual knowledge (Baron-Cohen 1994; Hobson, 1991, 1993; Tager-Flusberg, 2000). This chapter presents three studies investigating a more primitive form of affective relatedness in deaf children by considering the ability to voluntarily pose and imitate facial expressions of emotion. While the ability to encode facial expressions of emotion has been studied in other clinical populations with reported ToM difficulties, including children with Autism Spectrum Disorder (ASD) (e.g. Volker, Lopata, Smith & Thomeer, 2009), and congenitally blind children (e.g. Galati, Miceli & Sini, 2001; Galati, Sini, Schmidt & Tini, 2003; Roch-Levencq, 2006), this is yet to be studied in a population of congenitally deaf children.

Deaf children's early communication experience

Emotional development typically takes place in an auditory-linguistic context in which sound plays an important communicative role in very early interactions before language acquisition (Gray et al., 2007). Once spoken (or sign language) is acquired, children are privy to continuous commentary regarding their own and others' expressions of emotion (Dunn & Brown, 1993). Emotion understanding is continually refined via social interactions with siblings and peers, and both through conversing directly about emotions with parents and indirect emotional experiences e.g. when watching television (Dorr, 1985).

It has been reasoned that the relatively impoverished early communication between deaf infants and hearing parents impacts on preverbal deaf infants' early visual attention, which mirrors later delays in social-cognitive ToM (Meristro et al., 2012b). Inter-subjectivity refers to shared involvement with another person, recognising the other as a person with emotions and intentions and experiencing and sharing own intentions with the significant other (Loots & Devisé, 2003). Deaf children of hearing parents have been shown to spend less time in co-ordinated joint visual attention than hearing children and deaf signing children with deaf parents (Loots et al., 2005; Prezbindowski et al., 1998). While it seems logical that non-verbal behaviour in the visual domain could be preserved and even optimised in deaf children, research has highlighted that the majority of hearing parents are not sufficiently proficient in sign language and gestural communication to initiate and sustain social interactions and conversation revolving around others' beliefs (Spencer & Harris, 2006; Vaccari & Marschark, 1997).

Voluntary production of facial expressions

Emotion processing is closely linked to beliefs and desires (Astington, 1993; Wellman, 1990); a facial expression of emotion can display whether or not a desire has been fulfilled (happy or sad), or whether someone has had a false belief (surprise). Living in a social world, children develop notions about psychological processes that underpin everyday social occurrences (Harris, 1989). Emotion is prominent in social communication and it is arguable that it takes a central field in children's theorising; children interpret emotions, determining their relationship with desire and reality, facial expressions, vocal patterns, goals and action tendencies (Denham, 1997). According to Hobson (1991), early inter-personal relations are based upon perceptual-affective responsiveness towards bodily gestures, expressions and behaviours of others that leads to the knowledge of others' minds.

Being able to voluntarily pose facial expressions of emotion is thought to be an important aspect of the socialisation of emotion (Lewis et al., 1987). Effective non-verbal communication allows the sender to give an indication of emotional state or intentions to another person (Harrigan, Rosenthal & Scherer, 2008). The face in particular provides an important channel of information that can communicate subtle underlying inferences (Cohen & Ekman, 2005). As previously described, there are at least six basic facial expressions of emotion – happiness, sadness, anger, fear, disgust and surprise – that are thought to elicit activation of the same facial expressions and prototypical patterns of muscle activation (Ekman, 1972, 1978). These recognisable facial expressions allow the encoder to accurately convey facial expressions in these typical configurations that are similar across individuals (Russell & Fernandez-Dols, 1997). It is important, therefore, to both be able to interpret another person's emotion state by recognising emotion expressions (decoding), and to successfully communicate emotion (encode) through the face.

Children who communicate their emotions well are hypothesised to have better social skills and greater peer acceptance (Boyatzis & Satyaprasad, 1994; Field & Walden, 1982). Emotion production studies investigating this ability in typically developing children have revealed that children's accuracy and clarity of expression improves significantly with age; certain emotions, in particular, fear, are difficult to pose even for adults (Ekman, Hager & Friesen, 1980; Field & Walden, 1982; Lewis et al., 1987; Odom & Lemond, 1972). Field and Walden (1982) found a positive relationship between pre-schoolers who were more accurate at encoding facial expressions of emotion in an experimental situation and emotion expressiveness during free play.

Research on deaf children's non-verbal skill has focused solely on ability to *decode*, or recognise, others' expressions of emotion (e.g. Dyck et al., 2004; Hosie et al., 1998; Ludlow et al., 2010; Most & Aviner, 2009; Most & Michaelis, 2012). Some studies showing that deaf children make more errors in recognising or decoding facial expressions of emotion (e.g. Dyck et al., 2004; Ludlow et al., 2010) may be indicative of a difficulty in accurately encoding emotions. In studies 3 and 4 of this thesis, the deaf children were shown to be worse at recognising the emotion, disgust, in comparison to hearing control children. Being able to accurately recognise facial expressions of emotion has been linked to the ability to encode facial expressions of emotion in typically developed children (Field & Walden, 1982), some studies showing the former precedes the latter (Boyatzis & Satyaprasad, 1994). Impairments in emotion recognition has also been found to be paired with difficulties in emotion production, in particular, for the emotions fear, disgust and surprise (Goldman & Sripada, 2005), for example in adults with ASD (Macdonald et al., 1989) and schizophrenia (Mandal, Pandey & Prasad, 1998). It has been reasoned that deaf children's difficulties in non-verbal behaviour may result from early differences in inter-subjectivity and less experience with communication.

In addition, the ability to voluntarily express emotions may give an indication of how well children can modulate and control their facial expressions (Lewis & Michalson, 1983). It has been posited that greater control over voluntary facial expressivity is useful in regulating and masking emotions (Calkin, 1994). As children get older language becomes more important in regulating emotion. Guided by a socialisation process, both via practices of parents and other authorities, children develop more effective ways of expressing themselves; for example, using words to inform an adult or verbally express a grievance rather than hitting the person who elicited the feeling of anger (Thompson, 1994). ‘Display rules’ are a management technique learned that facilitates a person to separate expressions from feelings (Ekman & Friesen, 1669); the development of display rules enables children to minimise or intensify the expression of felt emotions appropriately depending on social context and cultural rules (Elfenbein, Beaupré, Lévesque & Hess, 2007).

Research with deaf children indicates a delay in understanding of display rules (Hosie et al., 2000) and difficulty in emotion regulation (Rieffe, 2012; Rieffe & Terwogt, 2004; Wiefferink, Rieffe, Ketelaar & Frijns, 2013). While hearing children gave pro-social reasons for masking their anger and showed concern for norm-maintenance, deaf children’s reasons were comparatively self-protective (Hosie et al., 2000). Deaf children’s less advanced emotion regulation skills have been implied by their more frequent and intense expression of negative emotions (Wiefferink et al., 2012). It is therefore conceivable that this may also impact on their non-verbal skills and ability to control the production of facial expressions.

Contrary to this hypothesis, deaf children’s reliance on the face to express emotion through sign language may suggest the opposite effect on their ability to encode emotion through facial expressions. There is evidence to suggest that the ability to decode and encode facial expressions of emotion is linked to the amount and quality of experience with nonverbal behaviour (Goldstein et al., 2000). In ASL (and likewise in BSL), facial expressions not only convey grammatical and syntactical information, but also emotion facial expressions are crucial accompaniments to manual signs for emotions. In the same way that pitch and tone of voice in English provides important emotion cues, the face is crucial to determining emotion meaning in sign language (Figure 3).

Figure 3. Left: BSL manual sign SAD: flat palm straight down across face (B2); Right: BSL sign SURPRISE: claw five hand shape. Accompanying facial expressions signify the intensity of the feeling.

Goldstein and colleagues theorised that given the importance of emotion expression in sign language, knowledge and experience of signing may result in greater adeptness at conveying emotions to others. Among hearing populations, Goldstein and Feldman (1996) found that signers were able to more accurately decode the six basic facial expressions of emotion than non-signers, and in a later study, Goldstein et al. (2000) found that signers were also able to more accurately *encode* facial expressions of emotion than non-signers. It could therefore be expected that deaf people who experience sign may be more successful at encoding emotion facial expressions than hearing people. In line with research exploring the development of typically developed children's non-verbal skills (Field & Walden, 1982), deaf people may develop display rules that adopt a high degree of intensity and clarity of expression that reflects the non-verbal style of communication to which they have been exposed. Conversely, as the majority of deaf children learn to sign late or are oral in their communication preference, this advantage in non-verbal communication afforded by experience with sign might not extend to all deaf people.

Emotion decoding methodology

The assessment of encoded facial expressions broadly falls into two categories: measurement studies and judgement studies (Volker et al., 2009; Wagner, 1997). The advantage of measurement studies is the employment of objective measures to assess facial behaviour. The emotion production studies presented in this chapter utilised Noldus FaceReader™ (version 4): software trained to classify the basic emotions as described by Ekman, detecting the features in the facial expressions according to the FACS (Ekman et al., 2002). The benefit of using FaceReader™ over the typical measurement study method, electromyography, is that it is less intrusive: a more covert method is particularly advantageous when conducting a study involving children, so to minimise distraction.

While FaceReader™ can provide an objective reading of the intensity of movement involved in changing facial expression, it is unable to evaluate internal-state information of the encoder that is conveyed through these facial movements (Wagner, 1997). In addition, a judgement methodology was implemented alongside FaceReader™ to provide a socially valid measure by which to assess the encoded facial expressions of emotion (Rosenthal, 1982). Social validity is an important consideration given the inherent social function of facial expressions: to inform others of an experienced emotional state (encode), so that others can interpret these signals (decode) within a social context (Rosenthal, 2005). From a developmental perspective, young children may only be able to pose partial facial movement, so relying solely on an exact coding system (e.g. FACS) may limit the facial expression assessment and miss recognisable aspects of emotion expression produced by the children (Lewis et al., 1987). This is particularly relevant given that previous studies have shown negative emotions, especially fear and anger, are difficult for both children (Ekman, 1980; Field & Walden 1982; Lewis et al., 1987; Odom & Lemond, 1972) and adults (Ekman, 1985; Ekman & Friesen, 1982) to encode.

The judges recruited in this study were required to make a categorical judgement of each viewed emotion expression by assigning one label from a short list, and also a rating of intensity in terms of degree the muscles involved in the facial expression (e.g. happiness) move away from a relaxed state (neutral) i.e. whether the viewed expression was subtle or exaggerated. The consideration of intensity is of value for two reasons. First, it has been shown that perceived intensity linearly increases with greater physical intensity and accuracy in judgement (Hess et al., 1997), suggesting that when emotion is interpreted out of context, it is a direct reading of the underlying emotional state. Second, intensity of expression has been shown to vary according to culture and the display rules adopted by each culture (Elfenbein, et al., 2007). Given that non-verbal behaviour is of particular importance in deaf communication (Goldstein et al., 2000), ratings of intensity could be informative in terms of how clear and expressive the deaf children are at conveying emotion in the face in comparison to hearing children.

Study 4a: voluntary emotion production

The aim of Study 4a was to compare the ability of deaf children to voluntarily encode the six basic emotion expressions in comparison to hearing controls. The advantage of using a posed methodology is that the cue for producing an emotion expression (e.g. *'show me anger'*) is unambiguous as opposed to eliciting an emotion by giving an example of a particular social situation (e.g. if a child builds a tower and another knocks it down he/she may be angry and/or sad) (Barth &

Archibald, 2003) and is independent of contagion that may occur when imitating a facial expression of emotion (Lewis et al., 1987); it therefore provides a picture of children's ability to voluntary encode facial emotion expressions on demand.

Study 4a hypotheses: Based on previous research the following hypotheses were drawn:

Hypothesis one: deaf and hearing children will perform similarly in the production of the emotions, happiness and surprise. It is argued the children are socialilsed to produce the facial expression of happiness (Field & Walden, 1982; Lewis et al., 1989) and even children with ASD have been found to be unimpaired in the voluntary production of happiness (Volker et al., 2009). It is thought that encoding and decoding happiness is visually simpler than negative emotions. Even if the full Duchenne smile (which includes activation of the muscles in the eye regions: orbicularis oculi muscle) is not produced, happiness can be easily encoded and recognised with a smile, and surprise with an open mouth (Adolphs, 2002).

Hypothesis two: Given that encoding has been shown to be more difficult than decoding for typically developing children (Boyatzis & Satyaprasad, 1994), *deaf children will be worse at producing the negative emotions, in particular the emotion, disgust.* There is some evidence to suggest that deaf children may be more expressive and accurate in producing emotion facial expressions due to use of sign language (Goldstein et al., 2000). However, based on Hobson's (1991) theory that perceptual-affective responsiveness towards expressions (as well as other gestures and behaviours) underpins the development of mentalising abilities, the deaf children of hearing parents may be worse at the production of negative emotions, in particular disgust. This is based upon deaf children of hearing parents' delays in ToM and potential delays in emotion recognition.

Hypothesis three: all children will be worse at encoding the negative emotions according to the Face Reader™ objective measure of facial expression behaviour, in particular fear and anger. This prediction is based on previous research that suggests that negative emotions are more difficult to produce on demand. It is thought that muscle movement is harder to control consciously for negative emotions (Ekman, 1985).

Method

Participants

Encoders: Five deaf children (three female) participated in this study ranging from 6 years and 7 months to 11 years and 2 months (mean = 8 years 6 months; SD = 1 year 9 months; Raven's IQ = 91.0; SD = 17.46). The children were recruited from three mainstream schools in the local area with attached hearing impaired units. Four of the children were moderate-severely deaf and one child was profoundly deaf with no known concomitant disorders such as mental retardation, attention deficit, or autism. All of the children received auditory amplification: three wore CAs and two children wore a HA. The deaf children were oral in their communication preference, using some SSE or BSL, but none were native signers. Table 18 displays the individual characteristics for each deaf participant.

Five typically developing children (3 female) also took part in the study matched to the deaf children for non-verbal ability and CA The children were aged between 6 years 10 months and 10 years 1 month (mean = 8 years 2 months; SD = 1 year 3 months; Raven's IQ mean = 98.0; SD = 10.37; Table 18). The children were recruited from local primary schools and were reported to be of average ability or above, with no apparent learning disabilities. Independent t-tests revealed no significant difference in CA (t (8) = .33, p = .75) or non-verbal ability (t (8) = -.77, p = .46) between the two groups. The deaf children performed within the average range on the BSL receptive language test (mean 101; SD = 14.07) and the hearing control children scored within the average range on the BPVS receptive language test (106.4, SD = 9.61).

Decoders: Thirty-five (22 female) adults took part in rating the children's emotion expressions, aged between 19 years and 6 months and 65 years and 1 month (mean = 30 years and 3 months; SD = 11 years). Participants were either: students recruited via Anglia Ruskin's on-line Psychology Research Participation System, receiving a course credit for their participation enabling them to recruit for their own studies; or unpaid community volunteers, recruited using an opportunity sampling method. Control participants were required to be free of neurologic or psychiatric disorders and a have negative family history of both psychiatric disorders and autistic spectrum disorder.

Table 18. *Deaf and Hearing Emotion Encoders' Individual Characteristics (CA, Non-verbal/Verbal Ability, EVT, Level of Hearing Loss, HA vs. CI)*

Participant	Group	Gender	CA	Standardized IQ	Standardised language (D: BSL; H: BPVS)	EVT (/12)	Level of deafness	HA vs. CI	Communication preference
1	D	M	9y0m	110	123	11	severe	HA	oral
2	D	M	7y0m	75	86	9	severe	CI	oral
3	D	F	11y2m	100	102	12	severe	CI	oral
4	D	F	8y10m	70	92	6	profound	CI	oral
5	D	F	6y7m	100	102	10	severe	HA	oral
6	H	M	8y11m	90	118	12			
7	H	M	7y7m	95	103	10			
8	H	F	10y1m	90	100	12			
9	H	F	6y10m	100	115	11			
10	H	F	7y6m	115	96	10			

Materials

The facial analysis software, Noldus FaceReader™ (version 4), was employed to classify the facial expressions of emotion produced by the children in this study. The software is programmed to detect and classify, in addition to 'neutral', the six basic emotions – happiness, sadness, anger, fear, disgust and surprise (Ekman, 1972). Digital video recordings of the children were taken (using Logitech Quickcam Orbit AF) and the videos analysed frame-by-frame. FaceReader™ first detects the face using the Viola-Jones algorithm (Viola & Jones, 2001) and then models the face based on the Active Appearance Method (Cootes & Taylor, 2000). The face is modelled according to key points (i.e. lips, eyebrows, nose and eyes) and the texture of the face entangled between these points. The texture of the face gives important information for classifying emotions, such as wrinkling in the skin and changes in eyebrow shape.

The classification itself occurs via an artificial neural network, the training for which involved over 10,000 manually annotated images (Bishop, 1995). FaceReader™ (version 4) has been validated both by analysing a standardised set of pictures of facial expressions: (Radboud Faces Database: Langer et al., 2010) at an overall accuracy rate of 90% (Bijlstra & Dotsch, 2011); and by comparing facial analysis of FaceReader™ (version 2) with two human observers, ranging from 99% agreement for 'neutral' to 70% agreement for 'disgust' (Terzis, Moridis & Economides, 2010; see www.noldus.com for more detail).

Procedure

Facial coding procedure: The ability to voluntarily encode the six basic emotion expressions was tested by videotaping the children producing each emotion. Prior to the emotion coding, the children completed an adaptation of the EVT (Dyck, et al., 2001), previously described in Chapter 4. The aim was to both prime them to think of the emotions and to check their comprehension. This involved the children having to recall scenarios and provide examples of when they, or another person, may experience the emotion (e.g. “I was sad when my pet dog died”). All children scored a minimum of 6 out of a total of 12, indicating an understanding of each of the 6 basic emotions (see Table 11). Additionally, during this process the children were shown labelled prototypical faces of each of the emotions to confirm their understanding. When the pre-test concluded, the materials were removed from the table.

The children were seated 60cm in front of a 14-inch portable computer, directly facing the screen. A digital video camera (Logitech Quickcam Orbit AF) was discreetly positioned behind the computer. To ensure the children were not too self-conscious or distracted by the video camera, recording began at the beginning of the session and continued throughout. The children’s face and shoulders were visible in the camera’s field of view. The experimenter was also sat behind the laptop, facing the child. First she explained that she was going to video record the child making each of the emotion faces. So not to influence the child’s response, the experimenter maintained a neutral facial expression and tone of voice, and smiled and praised the child’s response once he/she finished posing. To elicit a response, the experimenter said “show me…” followed by each of the six emotions – happiness, sadness, anger, fear, disgust and surprise. If the child seemed to be unfamiliar with the emotion word, a different form of the lexeme, or an appropriate synonym, was presented (e.g. ‘disgusting’ instead of ‘disgust’; ‘frightened’ or ‘scared’ instead of ‘fear’). The instructions were presented both orally and with the use of SSE to the deaf children. To prompt the most natural response, the children were not given a time limit; typically, they posed the emotion facial expressions for between two and seven seconds. Figure 4 shows examples of the peak expression of deaf children’s production of the emotions, surprise and anger.

[Images removed for confidentiality]

Figure 4. Screen shots of deaf children’s encoding of surprise and anger

Facial decoding procedure: The videos of the children’s encodings of the six basic emotions were decoded both via Noldus Face Reader™ (version 4) and via the ratings of 35 adult judges. In preparation for decoding, the experimenter watched the video recordings of each participant and noted the onset and end time of each emotion expression. Video editing software (VirtualDub 1.10.3) was used to analyse the videos to produce video clips of each emotion for each participant. The videos were then analysed frame-by-frame by running the clips through the Face Reader™ software. The software automatically calibrates to correct any bias towards a particular emotion expression for each face analysed, and then classifies the presence of each emotion with a value between ‘0’ and ‘1’: ‘0’ meaning that the expression is absent and ‘1’ meaning that it is fully present.

The adult decoders were informed that they were taking part in a study investigating children’s production of emotion facial expressions, but were kept blind of the knowledge of the characteristics of the two groups and the research hypotheses. To maintain social validity, the adult judges received no training in emotion expression decoding (Rosenthal, 2005). Each of the adult decoders rated the video clips individually in a quiet well-lit room in Anglia Ruskin University. Each decoder sat 60 cm in front of a 14-inch portable computer on which the video clips were presented. Instructions were given verbally explaining that to begin each video clip, the decoder needed to press ‘play’. After watching the video clip, the adult raters first needed to select the emotion they thought the child was attempting to portray by clicking on the appropriate emotion word. The six emotion words (happiness, sadness, anger, fear, disgust and surprise) were presented on the screen in a random order. Second, the adult decoders were asked to rate the intensity of emotion facial expression on a scale of 1-5: 1- not at all intense; 2- a bit intense; 3 – mildly intense; 4- very intense; 5 – extremely intense. If the adult decoder did not select the intensity rating, it was not possible to move onto the next video clip. A total of 60 video clips were shown to the decoders and the procedure took approximately 15 minutes. Once completed, the adult decoders were fully debriefed of the purpose of the study.

Design

A 2 (Group: Deaf vs. Hearing) x 6 (Emotion: Anger vs. Disgust vs. Fear vs. Happiness vs. Sadness vs. Surprise) mixed model experimental design was implemented. The factor, Group, was between participant, and the factor, Emotion, was within participant.

The children (encoders) were asked to produce the six emotion expressions in one of three randomized orders (A, B or C). These three versions were counterbalanced between participants. When rating the emotion expressions, the order of the 60 video clips presented to the decoders (adult hearing) was randomized.

Results

Judgement data: decoders' ratings of emotion encodings

The frequency of agreement between encoders (deaf and hearing) and the decoders (adult hearing) was calculated. Cross tabulations were created in the form of confusion matrices to show the relationship between the intended meaning of facial expressions (i.e. encoded targets) and the meaning (i.e. emotion labels) attributed by the decoders. Table 19 shows the raters' decoding of the deaf children's emotion production and Table 20 shows the raters' decoding of the hearing children's emotion production.

Table 19. *Cross Tabulations of Original Meanings (Row) of Deaf Children's Expressions (elicited by a Verbal Label) and Meaning Attributed by Judges (Column)*

	Happiness	Sadness	Anger	Fear	Disgust	Surprise	Total
Happiness	**95.4**	1.7	.6	0.0	2.3	0.0	100.0
Sadness	0.0	**85.7**	11.4	0.6	1.7	0.6	100.0
Anger	0.0	4.6	**72.6**	3.4	17.1	2.3	100.0
Fear	0.0	4.6	1.1	**66.9**	8.0	19.4	100.0
Disgust	0.0	9.7	29.1	2.3	**58.9**	0.0	100.0
Surprise	0.6	0.0	0.6	10.9	1.1	**86.9**	100.0

Table 20. *Cross Tabulations of Original Meanings (Row) of Hearing Children's Expressions (elicited by a Verbal Label) and Meaning Attributed by Judges (Column)*

	Happiness	Sadness	Anger	Fear	Disgust	Surprise	Total
Happiness	**96.6**	0.0	0.0	1.1	1.1	1.1	100.0
Sadness	0.6	**78.3**	0.0	0.0	18.3	2.9	100.0
Anger	8.0	16.0	**46.3**	2.9	22.3	4.6	100.0
Fear	1.1	1.1	0.0	**31.4**	25.7	40.6	100.0
Disgust	8.0	0.6	2.3	4.0	**72.6**	12.6	100.0
Surprise	0.6	1.7	0.0	30.3	1.1	**66.3**	100.0

For both groups, there was considerable difference between emotions in terms of how recognisable they were to the adult decoders; these accuracy values are summarised in Table 21. Happiness, followed by sadness and surprise were the most easily recognized emotions, followed by disgust, anger, and, finally – fear was the most difficult emotion facial expression to recognise. Overall, the expressions of the deaf children were recognised with higher accuracy than those of the hearing children. A chi-squared test of independence showed that this difference was statistically significant (Table 21). Deaf children also produced facial expressions for the emotions, sadness, fear, anger, and surprise, significantly more accurately recognised by the decoders. Conversely, hearing children's production of the emotion facial expression, disgust, was significantly more accurately recognised by decoders.

Table 21. *Chi-squared Test of Independence to show differences in Accuracy of Ratings for Target Expressions between Deaf and Hearing Children's Portrayals of Emotions (elicited by a Verbal Label)*

	Percentage correct		χ^2	Φ
Emotion	Deaf	Hearing		
Overall	75.62	65.24	40.08***	.14
Happiness	95.4	96.6	.03	.01
Sadness	85.7	78.3	3.27*	.10
Anger	72.6	46.3	13.37***	.20
Fear	66.9	31.4	43.94***	.36
Disgust	58.9	72.6	7.3**	.14
Surprise	86.9	66.3	17.8***	.26

NB. All χ^2 have 1 degree of freedom; *** $p<.001$, ** $p<.005$, * $p<.05$

Judgement data: decoders' ratings of intensity

Table 22 displays median intensity ratings of intensity for each emotion expression for deaf and hearing children. Mann-Whitney non-parametric tests were conducted to determine whether there were differences in decoders' ratings of intensity between the two groups. The decoders' ratings of intensity were significantly greater for deaf children's production of all emotion facial expressions in comparison to hearing children's expressions (Table 22).

Table 22. *Median Ratings of Intensity (1: not at all intense, to 5: extremely intense) and Mann-Whitney U-Test of difference between Encoder's Ratings of Intensity of Deaf and Hearing Children's Encodings of Emotion Facial Expressions (elicited by a Verbal Label)*

Emotion	Median rating: Deaf	Median rating: Hearing	U	*z*	*r*
Happiness	3 (2)	3 (1)	12138.5***	-3.49	-.19
Sadness	3 (2)	2 (1)	12827.5**	-2.75	-.15
Anger	4 (1)	3 (2)	11483.5***	-4.18	-.22
Fear	4 (1)	3 (2)	11473.5***	-4.24	-.23
Disgust	4 (1)	3 (2)	10719.5***	-5.06	-.27
Surprise	4 (1)	3 (2)	11313.5***	-4.39	-.23

Note. Inter-quartile range in parenthesis; ** p<.005, *** p <.001

Objective ratings of emotions

The sample videos were analysed via Noldus Facer Reader™ (version 4). The facial expressions in each clip were classified and transformed into ratings of the emotions of anger, disgust, fear, happiness, sadness, and surprise, ranging from 0 (the emotions is not detected by the software at all) to 1 (the expression detected corresponds uniquely to one emotion) in each analysed frame of the video. The scores obtained were averaged to create one score for each emotion displayed in each video. These scores were averaged in each group creating one score of intensity per group for each emotion (Table 23).

A Mixed ANOVA[5] was carried out to investigate whether the emotion expressions of both groups were different across the six emotions (Emotion x Group). Results revealed a non- significant main effect of Group F (1, 8) = .91, MSE = .02, p = .37, η^2 = .10, showing that overall, the expressions of deaf (M = .41, SD = .58) and hearing children (M = .34, SD = .53) were of similar intensity. A significant main effect of Emotion was present, F (5, 40) = 8.15, MSE = .08, p < .001, η^2 = .51. Further tests with Bonferroni corrections (adjusted significance level p <.003) revealed that surprise was rated as significantly more intense than anger and fear, and happiness was rated as being significantly more intense than fear (Table 24). The Group x Emotion interaction, F (5, 40) = .89, MSE = .08, p = .50, η^2 = .10, was not significant.

[5] The non-parametric Mann-Whitney U test revealed similarly non-significant difference between the two groups' FaceReader™ ratings for all emotions.

Table 23. *Means and SDs of FaceReader™ Recordings of Intensity of the Production of Emotions (elicited by a Verbal Label) by Deaf and Hearing Participants*

	Hearing		Deaf		Total	
Emotion	Mean	SD	Mean	SD	Mean	SD
Happiness	.82	.09	.68	.36	.75	.26
Sadness	.58	.31	.63	.23	.61	.26
Anger	.29	.31	.21	.34	.25	.31
Fear	.23	.19	.15	.16	.19	.17
Disgust	.14	.27	.41	.33	.27	.29
Surprise	.62	.38	.82	.11	.72	.28

Table 24. *Mean Differences between FaceReader™ Recordings of Production of Emotions (elicited by a Verbal Label) and Significance Levels (Bonferroni corrected)*

Emotion	Anger	Disgust	Fear	Happiness	Sadness	Surprise
Anger						
Disgust	-.019					
Fear	.066	.085				
Happiness	-.500	-.480	-.566**			
Sadness	-.354	-.335	-.420	.146		
Surprise	-.465**	-.446	-.532**	.034	-.112	

** p<.003

Discussion

This study was the first to investigate deaf children's ability to encode facial expressions of emotion. Both the judgement and FaceReader™ ratings are consistent with previous studies that have shown that children are best socialised to encode facial expressions of happiness on cue (Field & Walden, 1982; Lewis et al., 1989; Volker et al., 2009). The results are in support of hypothesis one as no significant differences in encoding of happiness was found between deaf and hearing children. While it can be argued that fixed-choice judgement studies with a bias towards negative categories make happiness easier to identify (Friedrickson, 1998; Russell, 1994), FaceReader™ provides an objective reading of facial movement that suggests that deaf and hearing children are both able to engage the muscles to successfully pose, at least partially, the prototypical configuration of the facial expression of happiness. As the children are able to pose 'happiness' on demand in the experimental setting, it can be supposed that it is within their control to manage this expression in a naturalistic setting (Lewis et al., 1987).

The judgement ratings of study 4a suggest that the deaf children encoded clearer facial expressions of emotion than hearing children as the expressions were significantly easier to decode for adult raters. In addition, deaf children were rated as producing significantly more intense expressions for all emotions, suggesting a higher level of expressiveness. These results do not support fully support hypothesis two, as deaf children encoded the typically more difficult negative emotions of sadness, fear, and anger (Field & Walden, 1982; Lewis et al., 1987; Ohman et al., 2001), as well as surprise, significantly *more* accurately than hearing children as judged by the adult raters.

These results support the alternative hypothesis that suggests that experience with non-verbal communication improves ability to produce facial expressions of emotion (Goldstein et al., 2000). Ekman (1972) acknowledged cultural variability in terms of when to mask, inhibit and exaggerate facial expressions of emotion. Goldstein et al. (2000) proposed that deaf signers may adopt a set of display rules that includes the expression of intense emotion that reflects exposure to non-verbal communication. This finding is interesting as none of the deaf children taking part in this study were native or even late-signing BSL users; all of the children were oral, but they had some experience with sign language (SSE and/or BSL) and all scored within the average range on the BSL receptive language test (Table 18). It could be, however, that this sample of deaf children were exceptional in their level of expressiveness and a wider sample of deaf children with a variety of sign language experience would need to be tested to confirm this suggestion.

It has been suggested that the ability to encode emotions requires the knowledge of display rules about controlling emotion expression (Lewis et al., 1987; Saarni, 1989). Being able to pull a happy face, for example, may reflect a child's understanding of the necessity to 'put on a good face' (Boyatzis & Satyaprasad, 1994). Yet anger is a non-affiliative emotion (Hess, Blairy & Kleck, 2000). It could be that the hearing children were more inhibited in encoding negative emotions, particularly anger, through a process of socialisation – it is less socially acceptable to display outbursts of anger (Lewis et al., 1987). Deaf children growing up in a hearing environment, with less frequent access to conversations about emotions, have been shown to be less likely to conceal anger. This has been attributed to a delay in the development of social display rules (Hosie et al., 2000); regulating emotions to protect the feelings of others may develop more slowly in deaf children (Wiefferink et al., 2012). A naturalistic study would shed light on how deaf children produce emotion expressions in a social context. Galati et al. (2003) found that blind children, who similarly display delays in understanding others emotions and intentions, were less likely to mask negative emotions than their sighted peers. At present, this remains a speculative explanation given that there was no direct assessment of display rules and it may be that deaf children were better at encoding anger because of greater experience and necessity to communicate via non-verbal methods.

As predicted, the deaf children were significantly poorer at producing the emotion, disgust, in comparison to the hearing children according to the adult raters. Given that deaf children were shown to be significantly poorer at recognising disgust in Studies 2 and 3, this result is not surprising given that impaired encoding of emotions has been linked with impaired recognition of emotion (Goldman & Sripada, 2005). The error scores reveal that deaf children's encodings of disgust were most commonly mistaken for anger. While this can partly be explained as misattribution errors of the human raters given that disgust is commonly mislabelled as anger even for adults (Widen & Russell, 2008c), it remains that a higher proportion of deaf children's emotion encodings of disgust were labelled as anger. It is possible that the deaf children may be delayed in developing an understanding of the term disgust. According to Russell and Widen (2003), children begin by generally differentiating emotions as positive and negative until they have a firm understanding of individual emotions which is learned through a process of socialisation. Young typically developed children use basic language with respect to physical disgust, such as *yucky* and *icky*, and a full understanding of the emotion term does not emerge until later (Russell & Widen, 2002). It is possible that some deaf children may be re-calling examples of moral disgust when encoding the emotion and interpreting this as being interchangeable with anger; typically developed children have been shown to choose an angry scowl over a disgust face for moral disgust stories (Pochedly & Zeman, in preparation). Yet this is unlikely given that typically developed children do not readily associate disgust with moral events as often as physically disgusting events (Danovitch & Bloom, 2009). Further exploration is needed to fully understand the emergence of deaf children's conceptualisation of disgust.

However, it is noteworthy that while the difference was not significant, the Face Reader™ rating for the production of disgust was *higher* for the deaf children than the hearing children. An anecdotal observation from watching the videos is that a feature of the hearing children's production of disgust was the distinctive tongue protrusion, which consequentially makes the encoding easier for the adult judges to recognise. Interestingly, in a laboratory study Reisenzein (2007) found that less than 10% of participants displayed the prototypical configuration of disgust (including AU 9) despite high self-reportings of experiencing the emotion. The nose scrunch is just one feature of the disgust expression, providing a signal aimed at avoiding smelling an unpleasant odour. In other naturalistic studies, the open mouth and tongue protrusion have also been identified as typical responses to disgust similarly to the hearing children in this study (Von dem Hagen et al., 2009).

For all children, the negative emotions – in particular, fear, disgust and anger - were the hardest to produce, providing support for hypothesis three and consistent with previous studies investigating emotion encoding abilities in typically developed children (e.g. Field & Walden, 1982; Lewis et al., 1987). The Face Reader™ data, in particular, showed low ratings of intensity for the negative emotions. Ekman (1985) suggested that the muscle movements for fear, disgust and anger are harder to consciously control, which suggests that the children (deaf and hearing) are less able to voluntarily produce the prototypical facial configurations of negative facial expressions. While developmentally young children may only be able to partially pose the basic facial expressions of emotion, the results of this study suggest children are still able to convey emotion through the face that is recognisable to adult decoders.

The higher rates of recognition of the adult rates emphasises the importance of including human judgement in emotion decoding assessment because, as social beings, they are able to decipher the socially inherent meaning that the children convey in their expressions of emotion (Rosenthal, 2005). Lewis et al. (1987) described children's emotion expressions as containing 'affect emblems' rather than the configuration of muscles typically associated with the prototypical expressions. One example is the alternative version of disgust (tongue protrusion) as previously discussed. Emotion has been shown to not only be recognised facially but also via associated gestures and movements e.g. cowering backwards for fear (Gelder, Snyder, Greve, Gerard & Hadjikhani, 2004). Krumhuber et al. (2013) suggest that emotion perception needs to be considered as a process involving a number of dynamic components that are combined together to produce meaning. Human raters' sensitivity to these emotion cues points to the advantage of using video clips, as opposed to the more common method of decoding emotion in still photographs to achieve a greater level of social and ecological validity.

Study 4b: emotion production in the context of signed stories

An alternative to using verbal prompts to ask a child to voluntarily produce a facial expression of emotion is to provide a contextual emotion story detailing a stereotypical emotion event (Boyatzis & Satyaprasad, 1994; Profyt & Whissell, 1991). Previous studies have shown that deaf children have been delayed in understanding emotion stories when responding verbally or by identifying the correct emotion facial expression (Gray et al., 2001, 2007; Rieffe, Terwogt & Smit, 2003). Gray et al. (2007) showed deaf children a series of illustrations depicting emotion-provoking events and asked them to match each scenario to a photograph of an emotion expression for the six basic emotions and to name that expression. While the deaf children showed a marked improvement with age, both younger and older children, overall, performed significantly worse than hearing controls.

In a different study of 9 and 11-year old deaf children who communicated in sign-supported Dutch, Rieffe et al. (2003) focused on short stories about sadness and anger to assess the emotion understanding. Results revealed that deaf children's explanations and emotional attributions concentrated on sadness caused by unfilled desires, where hearing children referred also to anger. It was suggested that as a result of limited opportunities to learn from their own and others' experiences via the auditory channel, deaf children have a constricted and less adaptable perception of emotional situations (Ziv et al., 2013).

In contrast, when carrying out a similar study to Gray et al. (2007), Ziv et al. (2013) found that while deaf Israeli signers displayed significantly worse performance, the deaf children with CIs' performance was comparable to the hearing children. It possible that some deaf children, despite having less opportunity to overhear conversations about emotions, can carefully observe prototypical situations and develop the knowledge that certain events provoke certain emotion reactions from others.

Interestingly, for typically developed children, when comparing emotion identification in the context of a story to emotion recognition in faces, a face inferiority effect has been found for some emotions (including disgust and fear) as opposed to a story detailing the cause and consequence of an emotion (Widen & Russell, 2010). It is reasoned that being able to identify emotion in stories is based upon a 'script' based understanding of emotions. However, it is also possible that deaf children may display delays in emotion understanding due to reduced opportunities to converse about their experiences, which in effect delays the acquisition of these scripts (Gray et al., 2007).

There are several potential limitations to the way in which emotion understanding of prototypical events has been studied in deaf children. In previous studies testing understanding of emotion stories, the story was signed and then shown in a series of illustrations (Gray et al., 2001; 2007), some deliberately leaving the protagonists' face blank (Odom et al., 1973; Ziv et al., 2013). Arguably, as emotion spontaneously occurs in an everyday context, when a deaf child tries to determine another's emotional and mental state, non-verbal cues, including facial expressions, are available as prompts. With the absence of auditory information, the contextualisation of stories and available non-verbal information is potentially even more crucial for deaf children.

A further disadvantage lies in presenting a story in two modes (signing followed by illustration), which creates a divide in attention in the same way that an interpreter poses a divide in deaf children's attention during a false belief task

(Schick et al., 2007). It is clearly more life-like and ecologically valid to have a signer simultaneously showing sign and facial expressions for all children using SSE. The importance of considering the socialisation of emotion has previously been acknowledged and operationalised by the experimenter's dramatisation of an emotional story to include emotional facial expressions and gestures (Denham, 1986, 1997; Denham, Zoller & Couchoud, 1994). Pre-recording emotion signed stories provides a further advantage to experimental validity due to the consistency that this provides in task administration.

Study 4b aimed to investigate deaf children's production of the six basic emotion expressions in social context by signing prototypical stories aimed at eliciting each of the emotions. Arguably a context-dependent task better reflects the processing occurring in everyday life for understanding emotions in the social contexts from which they stem (Ziv et al., 2013). The children were asked how the protagonist would feel in each situation. Whether the deaf children could verbally determine the target emotion of the story was considered, but they were also asked to display this by producing the emotion facial expression.

While a similar study was carried out with blind children (Roch-Levecq, 2006), this was the first study to assess deaf children's emotion understanding of stories by being asked to produce a facial expression of emotion in context. It is also the first study that examined deaf children's emotion understanding of stories through a battery of pre-recorded stories in SSE: a medium closer to that which deaf children experience in everyday life. In addition, being asked to encode a facial expression of emotion involves an entirely non-verbal response, which is an important consideration given that there may be a delay in deaf children's understanding of emotion terms/vocabulary.

Study 4b hypotheses: Based on the literature discussed, the following hypotheses were drawn. *Hypothesis one: Deaf and hearing children will show comparable performance both in verbal labelling and facial expression production of the emotions, happiness, sadness, fear and disgust.* Both hearing and deaf children have previously been shown to be able to identify situations that cause happiness and sadness (Gray et al., 2007; Ziv et al., 2013). These are reported to be the earliest emerging emotions (Widen & Russell, 2003). Given research suggesting a face inferiority effect for the later emerging emotions, disgust and fear (Widen & Russell, 2010) it was predicted that both deaf and hearing children would be able to encode and label fear in context. However, in light of the results of Study 4a, the deaf children may be rated as displaying more intense expressions of emotion.

Hypothesis two: all children will display greatest difficulty in identifying the emotion, surprise, in particular the deaf children. With the occurrence of an unexpected event, understanding surprise requires the attribution of a belief (Baron-Cohen et al., 1993). With delays in ToM understanding (Peterson & Siegal, 1995, 1998), this may pose particular problems for deaf children.

Method

Participants

See Study 4a.

Materials

To elicit an emotion response a series of 12 short stories of emotional events were created to present to the children in video format: two stories aimed at eliciting each of the six basic emotions (happiness, sadness, anger, fear, disgust and surprise). The English translations of the twelve stories are displayed in Appendix E. An example of a photo story board for one of the emotion signed stories can be found Appendix F. Five of the stories included were based on those used in a previous study by Widen and Russell (2002). The names of the children were changed to familiar English names that were easy to finger spell and American English terms were exchanged for British English ones (e.g. closet was exchanged with wardrobe). An additional seven stories were created for the purpose of this study. All stories were altered for ease of translation into Signed Supported English.

Pilot of Emotion Signed Stories: Prior to creating the video clips, the set of stories was piloted in an online study to ensure each story elicited the intended prototypical emotion. Fifty-three (39 female) Anglia Ruskin undergraduate students were recruited via the university's Psychology Research Participation System. Each student received a course credit for their participation enabling them to recruit for their own studies.

The students were shown a written version of each story in a random order and asked to first read the story and then freely state the key emotion thought to be experienced by the main character, typing the emotion word in the box provided. It was explicitly stated that only one emotion word should be provided. Participants were also asked to rate the intensity of the story on a scale from 1 (not at all intense) to 7 (very intense). An example story with an appropriate response was provided to ensure that the task was understood (Story: *"After school, Ann's friend came to play. They rode on their bikes in the garden. Ann's mum had baked a big chocolate cake";* Response: Emotion – *happy*; Intensity - #). The percentage of undergraduates who stated the target emotion (or an accepted synonym) for each story and the median rating of intensity can be found in Appendix E. High levels of accuracy were found for the stories eliciting happiness, sadness, anger, fear and disgust (>88.68%).

The second surprise story proved to be more difficult to produce the intended response (55.6%) in comparison to the first story that centred on the prototypical event of a surprise birthday party (81.13%). Many participants responded with the second emotion of happiness felt when receiving a new pet, which is typical as surprise, the event of something unexpected, is followed by either a positive or negative reaction. Some argue that surprise is a cognitive state rather than an emotion (Ortney & Turner, 1990). However, there is evidence for the universality of emotions, including surprise (Ekman et al., 1897), so it was decided that the surprise stories would still be included in this study, while remaining mindful of the potential confusion with happiness.

Following the pilot study, the stories were recorded in Signed Assisted English (SSE: BSL signs in English word order accompanied with Spoken English). Both the experimenter, who recorded the stories being signed, and the actor, had Level Two BSL. The actor was experienced in signing and using SSE with children as she worked as a teaching assistant in a primary school.

Procedure

Facial coding procedure: The procedure for data collection was similar to that of Study 4a. The ability to encode the six basic emotion expressions was tested by videotaping the children producing each emotion after having watched a signed story in SSE aimed at eliciting each emotion. The video recordings of the children's emotion facial expressions were then decoded, both via the ratings of 35 adult judges and analysis via the Noldus Face Reader™.

Study 4b followed immediately after Study 4a, meaning that the children had already been tested for comprehension of each of the six basic emotions. The children remained seated 60cm in front of a 14-inch portable computer, directly facing the screen. The video camera (Logitech Quickcam Orbit AF) was again discreetly positioned behind the computer and was set to record the whole session so not to be a distraction. The children's face and shoulders were visible in the camera's field of view. The experimenter was also sat behind the laptop, facing the child. First it was explained that the child needed to watch a story and then respond by saying an emotion/feeling word that explained how the main character felt, and to also make a face to express this. The instructions were presented both orally and with the use of SSE to the deaf children. An example story (the same as the pilot study example) was signed to the child by the experimenter to ensure that the task procedure was understood. Once each story had finished, the experimenter paused the video and asked the child to *"show me with your face how Ben/Ann feels."* To ensure the story had been comprehended, the child was also asked to explain why. If the child had misunderstood aspects of the story, the video clip was shown a second time. Additionally, the verbal or signed response of each child was recorded by the experimenter. The task lasted approximately 15 minutes.

Facial decoding procedure: The preparation for decoding was as per Study 4a. The decoding procedure was the same with the exception of the task duration being 20 minutes and a total of 120 video clips were presented to the raters.

Design

The study's design was the same as Study 4a.

Results

Judgement data: decoders' ratings of emotion encodings

The frequency of agreement between encoders (deaf and hearing) and the decoders (adult hearing) was calculated. Cross tabulations were created in the form of confusion matrices to show the relationship between the intended meaning of facial expressions (i.e. encoded targets) and the meaning (i.e. emotion labels) attributed by the decoders. Table 25 shows the raters' decoding of the deaf children's emotion production and Table 26 shows the raters' decoding of the hearing children's emotion production.

For both groups, there was considerable difference between emotions in terms of how recognisable they were to the adult decoders; these accuracy values are summarised in Table 27. For the hearing children, happiness, followed by sadness and disgust were the most easily recognised emotions, with fear, anger and surprise being more difficult emotion facial expressions to recognise. For the deaf children, sadness was the easiest emotion to recognise, followed by happiness, disgust and fear, with anger and surprise being the most difficult facial expression of emotion to recognise. Overall, the expressions of the deaf children were recognised with higher accuracy than those of the hearing children (71.0% vs. 66.05%). A chi-squared test showed that this difference was statistically significant (Table 27).

Table 25. *Cross Tabulations of Original Meanings (Row) of Deaf Children's Expressions (elicited by Stories) and Meaning Attributed by Judges (Column)*

	Happiness	Sadness	Anger	Fear	Disgust	Surprise	Total
Happiness	**76.86**	.86	.29	5.14	8.86	8.0	100.0
Sadness	.86	**93.14**	1.14	0.57	2.57	1.17	100.0
Anger	0.0	31.14	**56.86**	6.86	3.43	1.71	100.0
Fear	0.0	8.0	.86	**70.86**	4.57	15.71	100.0
Disgust	0.0	2.57	5.43	12.0	**77.71**	2.29	100.0
Surprise	38.57	.57	0.0	10.9	0.0	**50.57**	100.0

Table 26. *Cross Tabulations of Original Meanings (Row) of Hearing Children's Expressions (elicited by Stories) and Meaning Attributed by Judges (Column)*

	Happiness	Sadness	Anger	Fear	Disgust	Surprise	Total
Happiness	**93.43**	.57	.57	.57	.86	4.0	100.0
Sadness	0.0	**90.86**	.29	4.0	4.57	.29	100.0
Anger	8.86	30.29	**44.57**	4.0	11.43	.86	100.0
Fear	0.0	10.29	0.0	**47.71**	10.86	31.14	100.0
Disgust	1.43	1.14	1.71	10.29	**78.29**	7.14	100.0
Surprise	41.71	.57	1.43	12.86	2.0	**41.43**	100.0

Table 27. *Chi-squared Test of Independence to show differences in Accuracy of Ratings for Expressions between Deaf and Hearing Children's Portrayals of Emotions elicited by Stories*

	Percentage correct			
Emotion	Deaf	Hearing	χ^2	Φ
Overall	71.0	66.05	11.94***	.05
Happiness	76.86	93.43	37.99***	.23
Sadness	93.14	90.86	1.24	.04
Anger	56.86	44.57	10.57***	.12
Fear	70.86	47.71	38.83***	.24
Disgust	77.71	78.29	.03	.01
Surprise	50.57	41.43	5.89*	.09

Note. All χ^2 have 1 degree of freedom; *** $p<.001$, ** $p<.005$, * $p<.05$

Deaf children also produced facial expressions for the emotions, fear, anger, and surprise, significantly more accurately recognised by the decoders. Conversely, hearing children's production of the emotion facial expression, happiness, was significantly more accurately recognised by decoders. There was no significant difference between recognition rates of deaf and hearing children's production of sadness or disgust.

Verbal responses to signed emotional stories

Table 28 shows the percentage of correct verbally (or signed) responses to the question, *"how does Ann/Ben feel?",* in terms of correctly labelling the target emotion of the stories (Children's individual results for their verbal responses can be found in Appendix G). Happiness, sadness, fear and disgust were correctly identified by all of the deaf and hearing children ('excited' was accepted as a synonym for happiness; 'scared' and 'afraid' were accepted a synonyms for fear; and 'didn't like' was accepted for disgust). For anger, most other responses were labelled as sadness (or stressed), and for surprise, the majority of other responses were labelled as happiness (or excited).

Table 28. *Percentage Correct Identification of Target Emotion for Verbal Responses to Signed Emotional Stories*

Emotion story	*Deaf*	*Hearing*
Happiness 1	5/5	5/5
Happiness 2	5/5	5/5
Happiness	**100%**	**100%**
Sadness 1	5/5	5/5
Sadness 2	5/5	5/5
Sadness	**100%**	**100%**
Anger 1	2/5	4/5
Anger 2	4/5	3/5
Anger	**60%**	**70%**
Fear 1	5/5	5/5
Fear 2	5/5	5/5
Fear	**100%**	**100%**
Disgust 1	5/5	5/5
Disgust 2	5/5	5/5
Disgust	**100%**	**100%**
Surprise 1	3/5	3/5
Surprise 2	2/5	2/5
Surprise	**50%**	**50%**

Note. Children identifying happiness in addition to surprise were scored as correctly identifying the target emotion

Judgement data: decoders' ratings of intensity

Table 29 displays median intensity ratings of intensity for each emotion expression for deaf and hearing children. Mann-Whitney non-parametric tests were conducted to determine whether there were differences in decoders' ratings of intensity between the two groups. The decoders' ratings of intensity were significantly greater for deaf children's production of all emotion facial expressions in comparison to hearing children's expressions.

Table 29. *Median Ratings of Intensity (1: not at all intense, to 5: extremely intense) and Mann-Whitney U-Test of difference between Encoder's Ratings of Intensity of Deaf and Hearing Children's Encodings of Emotion Facial Expressions (elicited by Stories)*

Emotion	Median rating		U	*Z*	*r*
	Deaf	Hearing			
Happiness	3 (1)	3 (1)	42781.5***	-7.15	-.27
Sadness	3 (2)	3 (1)	46949.0***	-5.64	-.21
Anger	4 (1)	3 (1)	36159.0***	-9.70	-.37
Fear	3 (2)	3 (1)	47780.5***	-5.25	-.20
Disgust	4 (1)	3 (1)	52286.0***	-3.51	-.13
Surprise	4 (1)	3 (1)	38568.0***	-8.91	-.34

NB. Inter-quartile range in parenthesis; *** p <.001

Objective ratings of emotions

The sample videos were analysed using the software FaceReader™. To recap, the software detects the features in facial expressions associated to the FACS (Ekman et al., 2002) and transforms such values into ratings of the emotions ranging from 0 (the emotions is not detected by the software at all) to 1 (the expression detected corresponds uniquely to one emotion) in each analysed frame of the video. The scores obtained were averaged to create one score for each emotion displayed in each video. These scores were averaged in each group creating one score of intensity/accuracy per group for each emotion (Table 30).

A Mixed ANOVA was carried out to investigate whether the emotion expressions of both groups were different across the six emotions (Emotion x Group). Results revealed a non- significant main effect of Group F (1, 18) = .16, MSE = .08, p = .69, η^2 = .01, showing that overall, the expressions of deaf and hearing children were of similar intensity and accuracy. A significant main effect of Emotion was present, F (5, 90) = 20.6, MSE = .07, p < .001, η^2 = .62. Further tests with Bonferroni corrections (adjusted significance level p <.003) revealed that happiness was significantly more intense and accurately detected than all other emotions except sadness, and sadness was significantly more intense and accurately detected than anger, disgust and surprise (Table 31). The Group x Emotion interaction, F (5, 90) = 2.27, MSE = .08, p = .05, η^2 = .07, was not significant.

Table 30. *Means and SDs of FaceReader™ recordings of Intensity of the Production of Emotions (elicited by Stories) by Deaf and Hearing Participants*

	Deaf		Hearing		Total	
Emotion	Mean	SD	Mean	SD	Mean	SD
Happiness	.70	.27	.87	.10	.79	.21
Sadness	.64	.23	.68	.36	.66	.30
Anger	.10	.20	.27	.34	.19	.28
Fear	.04	.06	.20	.26	.12	.20
Disgust	.35	.31	.11	.17	.23	.27
Surprise	.45	.36	.28	.38	.36	.37
Total	.38	.29	.40	.29	.39	.28

Table 31. *Mean differences between FaceReader™ recordings of Emotions (elicited by Stories) and Significance levels (Bonferroni corrected)*

Emotion	Anger	Disgust	Fear	Happiness	Sadness	Surprise
Anger						
Disgust	-.040					
Fear	.068	.108				
Happiness	.601***	-.561***	-.669***			
Sadness	-.474***	-.434***	-.542***	.127		
Surprise	-.179	-.139	-.247	.422***	.295	

** *p*<.001

Discussion

This was the first study to investigate deaf children's emotion understanding through the production of facial expressions in the context of emotion signed stories. As predicted in hypothesis one, the deaf and hearing children showed comparable performance on sadness, both in terms of the verbal response and in encoding the emotion. Similarly for happiness, all children correctly labelled the emotion, yet surprisingly deaf children's encodings were recognised significantly less accurately by the adult raters than the hearing children's. Yet the objective FaceReader™ results revealed no significant difference between deaf and hearing children's expressions. Examining the confusion matrix shows that deaf children's expressions of happiness were confused with fear and disgust by some of the adult raters. It is possible that the adult raters were confused by the deaf children's intensity of expressions. An anecdotal observation from watching the videos is that some of the deaf children appear screw up their face in excitement which might be mistaken for a negative emotion of the same intensity.

A striking finding is that deaf children's labelling of all other basic emotions was comparable to the hearing group children in contrast to the majority of previous research on deaf children's understanding of emotion stories (Gray et al., 2001; 2007; Rieffe et al., 2003) but in line with the oral deaf children with CIs in Ziv et al.'s (2013) study: all children were correctly able to label fear and disgust, in addition to happiness and sadness, with 100 per cent accuracy. A distinction between the present study and previous studies lies in methodology. Clear contextual cues were provided in the signed emotion stories including facial expressions and gesture that illustrated the emotive content of the stories. Despite being unable to overhear conversations revolving around emotions and mental states, it appears that deaf children have the potential to carefully observe events that typically provoke certain emotion reactions (Ziv et al., 2013). In addition, three of the deaf children were aided with CIs and all children's language was within the average range, meaning these children potentially had sufficient access to emotion conversation. Caution should be drawn to this interpretation due to the small sample in this study - emotion understanding assessed through the signed emotion stories needs to be tested on a wider sample of deaf children with varying language abilities to better support this theory. However, these results are suggestive that some deaf children are able to develop emotion understanding at a similar rate to their hearing peers.

Anger and surprise were more difficult emotions for both groups to label, with anger most commonly mistaken as sadness, and surprise as happiness. This is consistent with previous research examining labelling errors in both deaf children (Gray et al., 2007; Ziv et al., 2013) and younger hearing children (Widen & Russell, 2008b) for more complex emotions. It is reasoned that younger children typically label sadness as anger because sadness is applied generally to negative emotions until children can more effectively discriminate between characteristics that elicit different negative emotional states (Russell & Widen, 2003). The error data showing that surprise was most often interpreted as happiness is also consistent with prior research that shows that young children tend to link surprise to happy events rather than negative ones (Gray et al., 2007; Hadwin & Perner, 1991). Some children, however, labelled the surprise stories as fear. These results were also in line with the adult ratings of surprise stories in the pilot study (Appendix E): lower accuracy rates for surprise were found as participants attributed happiness to the character receiving a new pet rabbit, which could be anticipated assuming that the child would be happy to receive a new pet. Ortney and Turner (1990) criticise the inclusion of surprise as a basic emotion as it always is followed by a positive (happiness) or a negative (fear) response. Despite the controversy surrounding the emotion, surprise, deaf children paralleled hearing children in the pattern of response, both in terms of level of performance and in errors, indicating a common conceptual understanding of emotion (Gray et al., 2007).

Importantly, deaf children's production of sadness, fear, anger and surprise was recognised with a significantly higher level of accuracy by the adult raters, and all emotions produced by deaf children were rated as significantly more intense than hearing children's. As per Study 4a, these results support the theory that experience with sign and non-verbal communication results in a greater ability to voluntarily encode facial expressions of emotion (Goldstein et al., 2000). Consistent with Study 4a, however, there were no significant differences between the FaceReader™ ratings of emotion encodings of the deaf and hearing children again suggesting little difference between the two groups of children specifically in the activation of muscles involved in producing the prototypical configurations of facial expressions. Again this suggest that while there were no differences in the two groups in terms of ability to produce the prototypical expressions, the deaf children were more able to encode emotion expression that were more readily recognisable to adult raters. As the deaf children's emotion encodings were rated as being significantly more intense than the hearing children's, this is again indicative of a higher level of expressiveness that may reflect the display rules of deaf communication (Goldstein et al., 2000).

Another noteworthy finding is that all deaf children were able to correctly label disgust in both stories, and no differences were found between deaf and hearing children's encodings of emotion facial expressions. This suggests that the deaf children in this study did have a conceptual understanding of physical disgust. Deaf (and hearing) children's better performance in labelling and producing the emotion expression of disgust in the context of a story over a facial expression is consistent with Widen and Russell's (2013) research on disgust. A face *inferiority* effect over cause and consequence elicited through a story has been found for disgust (Russell, 2002, 2008a, 2008b, 2010, 2013) as well a fear and the later emerging self-conscious emotions (Widen & Russell, 2010). In opposition to the theory that facial expressions are an innate signalling system (e.g. Ekman, 1994; Izard, 1994), Widen and Russell (2010) theorise that a child's understanding of emotion is rooted within a narrative structure that is absent in a facial expression, known as 'scripts' that are operationalised in stories. It is important to highlight, however, that the results of the present study may be exceptional as identification rates of disgust in stories was 100% as opposed to 69% overall in the studies referred to by Widen and Russell (2013). Alternatively, the high level of labelling accuracy may be reflective of the additional gestures and expressions afforded by presenting the tasks in signed English alongside a spoken rendition of the story, further drawing attention to the importance of contextual cues in emotion understanding.

Study 4c: voluntary imitation of emotion facial expressions

A third way to elicit the encoding of facial expressions of emotion is to ask participants to voluntarily imitate emotion facial expressions of others. Imitation is thought to be important to the acquisition of social skills as it aids 'self-other processing' that may provide the basis for inferring goals and intentions of others in social interactions (Meltzoff & Decety, 2003; Shih et al., 2010). It has been proposed that the internal simulation of an observed facial expression enables the understanding of others' emotions. There is evidence to suggest that imitation occurs during the recognition of emotions in the form of contagion: a visual representation allows us to experience what another person is feeling, and so infer their emotional state (Atkinson & Adolphs, 2005). Harris' (1992) simulation theory argues that ToM is an evolving process of being able to focus on another's perspective while putting aside your own point-of-view. The first step of this model according to Harris is the echoing of another person's intentional stance via their own perceptual or emotional system. Imitation bears a resemblance to attributing mental states in that both involve transferring the perspective of another individual to oneself (Williams, Whiten, Suddendorf & Perrett, 2001).

Being able to understand and identify with how others feel is critical to success in social interactions. It has been argued that being able to *overtly* (voluntarily) mirror emotions displayed by others is likely to play a crucial role in social situations as it sends a signal to the other person that they have been understood (Pfeifer, Iacoboni, Mazziotta & Dapretto, 2008). When a person experiences intense sorrow or happiness it is expected that another person will respond with appropriate emotion expression. Upon identifying that someone appears deeply sad it would be considered inappropriate to respond either with flat affect or with a grin of intense happiness reflecting the person's own emotion state.

Imitation of emotion expressions has not previously been studied in a population of deaf children which is surprising given the reported delays in ToM and some evidence of difficulties in emotion recognition. Rogers and Pennington (1991), based on Hobson's (1991) inter-subjectivity theory proposed that observed problems in imitation in children with ASD were linked to deficits in emotion perception and ToM. While deaf children do not display the same level of social and communication difficulties as children with ASD, with the indication of a possible difficulty in emotion recognition (e.g. Dyck et al., 2004; Ludlow et al., 2010) and joint attention (Loots et al., 2005; Prezbindowski et al., 1998), it is conceivable some difficulties in emotion mimicry may also be found in some deaf children. However, the results of the emotion recognition studies in this thesis (Studies 1, 2 and 3) have found deaf children's abilities that are comparable with hearing controls consistent with some other prior studies (e.g. Hosie et al., 1998; Most & Aviner, 2009; Ziv et al., 2013), with the exception of the more difficult emotion of disgust, suggesting that it is probable that imitation – an early indication of understanding the minds of others – will not be impaired.

Study 4c aimed to test deaf children's ability to voluntarily imitate facial expressions of emotion. The majority of imitation studies conducted with other populations have utilised static images to elicit a response (e.g. children: Field & Walden, 1992; ASD: Oberman, Winkielman & Ramachandran, 2009). In this study, the deaf and hearing children were shown a series of video clips taken from the ADFES (Van der Schalk, et al., 2011), which were selected given that dynamic emotional displays have been shown to be more physiologically arousing (e.g. Sato & Yoshikawa, 2004) and prompt stronger facial mimicry (e.g. Sato et al., 2008) than static images. Moreover the inclusion of real human faces is closer to natural expressions experienced in everyday life, meaning that dynamic stimuli have greater ecological validity.

Study 4c Hypotheses: While some studies have found poor performance in emotion recognition tasks for deaf children, Studies 2 and 3 of this thesis showed similar performance to hearing children in emotion recognition, and Studies 4a and

4b have shown similar performance in emotion production. It was predicted that *deaf children would show comparable imitation of emotion expressions to hearing children, with the exception of a poorer production of disgust*. Based on the results of Studies 4a and 4b, it was expected that the adult raters would consider the deaf children's emotion encodings to be more intense than the hearing children's.

Method

Participants

See Study 4a.

Materials

Experimental stimuli composed of 18 dynamic clips of human faces selected from the ADFES (Van der Schalk et al., 2011). Three sets of videos clips of the six basic emotions - happiness, sadness, anger, disgust, fear and surprise – portrayed by four of the actors were selected. For two of the actors (one male), each of the six basic emotions were used. For a further two actors, three of the emotions – sadness, fear and disgust – were selected from one actor (male); and the other three emotions – happiness, anger and surprise - were selected from the other (female), to ensure a balance of gender in the experimental stimuli (Table 32). Stimuli were displayed in the centre of a 14 inch computer screen using E-Prime v2.0 Professional (Schneider et al., 2002). Each clip was 5 seconds in duration. For a description of Face Reader™, see Study 4a.

Table 32. *Dynamic Video clips of Emotion selected from ADFES (Van de Schalk et al., 2011) for Emotion Mimicry*

	Emotion Video Clips
Male 2	Happiness, Sadness, Anger, Fear, Disgust, Surprise
Male 6	Sadness, Fear, Disgust
Female 2	Happiness, Sadness, Anger, Fear, Disgust, Surprise
Female 5	Happiness, Anger, Surprise

Procedure

Facial coding procedure: The ability to mimic the six basic emotion expressions was tested by videotaping the children copying 18 video clips of real human actors displaying each of the six emotions. The video recordings of the children's emotion facial expressions were then decoded, both via the ratings of 35 adult judges and analysis via the Noldus Face Reader™ software.

The children were tested for comprehension of each of the six basic emotions as detailed in Study 4a. The children were seated 60cm in front of a 14-inch portable computer, directly facing the screen. The video camera (Logitech Quickcam Orbit AF) was again discreetly positioned behind the computer and was set to record the whole session so not to be a distraction. The children's face and shoulders were visible in the camera's field of view. The experimenter was also sat behind the laptop, facing the child. First it was explained that the child needed to watch the emotion video clips and copy the facial expressions that they saw. The instructions were presented in SSE to the deaf children. Three examples were given initially to ensure to ensure that the task procedure was understood. The test itself consisted of one block with 18 video clips showing three of each of the six emotions. Each stimulus was presented on the screen one at a time in a random order. The videos lasted for five seconds beginning from a neutral pose to the apex of the expressed emotion. The task lasted approximately 5 minutes.

Facial decoding procedure: As per Studies 4a and 4b, the experimenter watched the video recordings of each participant and noted the onset and end time of each emotion expressions in preparation for decoding. Video editing software (VirtualDub 1.10.3) was used to analyse the videos frame-by-frame and produce video clips of each emotion for each participant. The decoding procedure was the same as Study six with the exception of the task duration being approximately 30 minutes and a total of 180 video clips were presented to the raters. A break between watching video clips could be taken if necessary.

Design

See Study 4a.

Results

Judgement data: decoders' ratings of emotion encodings

The frequency of agreement between encoders (deaf and hearing) and the decoders (adult hearing) was calculated. Cross tabulations were created in the form of confusion matrices to show the relationship between the intended meaning of facial expressions (i.e. encoded targets) and the meaning (i.e. emotion labels) attributed by the decoders. Table 33 shows the raters' decoding of the deaf children's production of mimicked emotions and Table 34 shows the raters' decoding of the hearing children's production of mimicked emotions.

For both deaf and hearing children, there were differences in terms of how recognisable the production of the mimicked emotions was to the adult decoders. For all children, happiness followed by surprise was the easiest, and fear followed by anger was the hardest emotions to recognise. In contrast to the previous two emotion production studies, overall the expressions of the hearing children were recognised with higher accuracy than those of the deaf children. A chi-squared test showed that this difference was statistically significant (Table 35). However, group comparisons for each of the separate emotions showed that hearing children only mimicked the emotion, disgust, significantly more accurately recognised by the decoders. There was no significant difference between recognition rates of deaf and hearing children's production of all other emotions.

Table 33. *Cross Tabulations of Original Meanings (Row) of Deaf Children's Mimicked Expressions and Meaning Attributed by Judges (Column)*

	Happiness	Sadness	Anger	Fear	Disgust	Surprise	Total
Happiness	**91.81**	.76	.38	.57	3.62	2.86	100.0
Sadness	2.29	**69.71**	10.48	2.29	12.57	2.67	100.0
Anger	.19	29.90	**58.29**	2.67	8.00	.95	100.0
Fear	3.43	3.81	1.71	**52.76**	18.67	19.62	100.0
Disgust	.00	9.33	19.62	3.81	**62.29**	4.95	100.0
Surprise	.00	.57	.38	18.48	1.33	**79.24**	100.0

Table 34. *Cross Tabulations of Original Meanings (Row) of Hearing Children's Mimicked Expressions and Meaning Attributed by Judges (Column)*

	Happiness	Sadness	Anger	Fear	Disgust	Surprise	Total
Happiness	**92.95**	.57	.19	1.52	2.86	1.90	100.0
Sadness	.38	**73.52**	10.10	2.86	10.29	2.86	100.0
Anger	.00	21.14	**63.05**	2.10	11.62	2.10	100.0
Fear	.57	11.62	6.29	**49.71**	9.33	22.48	100.0
Disgust	.19	3.62	18.67	2.86	**73.52**	1.14	100.0
Surprise	.57	2.48	.57	15.43	1.33	**79.62**	100.0

Table 35. *Chi-squared Test of Independence to show differences in Accuracy of Ratings for Mimicked Expressions between Deaf and Hearing Children's Portrayals of Emotions*

	Percentage correct		χ^2	Φ
Emotion	Deaf	Hearing		
Overall	69.02	72.06	7.04**	.03
Happiness	91.81	92.95	.49	.02
Sadness	69.71	73.52	1.87	.04
Anger	58.29	63.05	2.49	.05
Fear	52.76	49.71	.98	.03
Disgust	62.29	73.52	15.21***	.12
Surprise	79.24	79.62	.02	.004

Note. All χ^2 have 1 degree of freedom; *** $p<.001$, ** $p<.01$

Judgement data: decoders' ratings of intensity

Table 36 displays median intensity ratings of intensity for each emotion expression for deaf and hearing children. Mann-Whitney non-parametric tests were conducted to determine whether there were differences in decoders' ratings of intensity between the two groups. The decoders' ratings of intensity were significantly greater for deaf children's production of all emotion facial expressions in comparison to hearing children's expressions, with the exception of disgust.

Table 36. *Median Ratings of Intensity (1: not at all intense, to 5: extremely intense) and Mann-Whitney U-Test of difference between Encoder's Ratings of Intensity of Deaf and Hearing Children's Mimicked encodings of Emotion Facial Expressions*

Emotion	Median rating: Deaf	Median rating: Hearing	U	*z*	*r*
Happiness	3 (2)	3 (1)	99343.5***	-8.22	-.25
Sadness	3 (1)	2 (1)	109201.5***	-6.14	-.19
Anger	3 (2)	2 (1)	93928.5***	-9.43	-.29
Fear	3 (1)	3 (1)	94171.5***	-9.40	-.29
Disgust	3 (1)	3 (1)	137075.0	-.16	-.01
Surprise	3 (1)	3 (2)	103020.5***	-7.45	-.24

Note. Inter-quartile range in parenthesis; *** $p < .001$

Objective ratings of emotions

The sample videos were analysed using the Noldus software, FaceReader™. Features in facial expressions associated to the FACS (Ekman et al., 2002) were detected and transformed into ratings for each emotion ranging from 0 (the emotions is not detected by the software at all) to 1 (the expression detected corresponds uniquely to one emotion) in each analysed frame of the video. The scores obtained were averaged to create one score for each emotion displayed in each video. These scores were averaged in each group creating one score of intensity/accuracy per group for each emotion Table 37.

A Mixed ANOVA was carried out to investigate whether the mimicked emotion expressions of both groups were different across the six emotions (Emotion x Group). Results revealed a non- significant main effect of Group F (1, 28) = .14, MSE = .10, $p = .71$, $\eta^2 = .01$, showing that overall, the expressions of deaf and hearing children were of similar intensity and accuracy. A significant main effect of Emotion was present, $F\ (5, 140) = 14.73$, MSE = .11, $p < .001$, $\eta^2 = .35$. Further tests with Bonferroni corrections (adjusted significance level $p < .003$) revealed that fear was significantly less intense and less accurately detected than all other emotions except disgust, and disgust was significantly less intense and accurately detected than happiness and surprise (Table 38). The Group x Emotion interaction was also significant, $F\ (5, 140) = 2.34$, MSE = .11, $p = .05$, $\eta^2 = .08$. Deaf children trended towards producing more intense and accurate expressions of anger, and hearing children trended towards producing more intense and accurate expressions of disgust, but further comparisons with Bonferroni corrections (adjusted significance level $p < .008$) showed that there were no differences between the groups for any of the six emotions (Table 37).

Table 37. *Means and SDs of FaceReader™ recordings of Intensity of the Production of Mimicked Emotions by Deaf and Hearing Participants*

	Deaf		Hearing		Total		Multiple comparisons (deaf vs hearing)
Emotion	Mean	SD	Mean	SD	Mean	SD	
Happiness	.69	.33	.73	.38	.71	.35	$t(28) = -.34$, $p = .74$
Sadness	.56	.36	.55	.37	.55	.36	$t(28) = .14$, $p = .89$
Anger	.57	.37	.29	.33	.43	.37	$t(28) = 2.23$, $p = .03$, ns
Fear	.06	.22	.14	.26	.10	.24	$t(28) = -.94$, $p = .35$
Disgust	.21	.27	.44	.33	.33	.31	$t(28) = -2.12$, $p = .04$, ns
Surprise	.75	.30	.59	.35	.67	.33	$t(28) = 1.32$, $p = .20$
Total	.48	.31	.46	.34	.47	.33	

Table 38. *Mean differences between FaceReader™ recordings of Mimicked Emotions and Significance Levels (Bonferroni corrected)*

Emotion	Anger	Disgust	Fear	Happiness	Sadness	Surprise
Anger						
Disgust	.101					
Fear	.325***	.225				
Happiness	-.279	-.379***	-.604***			
Sadness	-.126	-.226	-.451***	.153		
Surprise	-.243	-.344***	-.569***	.036	-.118	

*** p<.001

Discussion

This is the first study to investigate voluntary emotion mimicry in deaf children. As predicted, no differences were found between adult ratings of deaf and hearing children's productions of the emotions, happiness, sadness, anger, fear, and surprise, but deaf children's encoding of disgust was significantly less accurately recognised than hearing children's encoding. While not statistically significant, the Face Reader™ data revealed a trend towards hearing children producing more accurate and intense productions of disgust than deaf children. These results mirror the earlier findings of Studies 2, 3 and 4a, which demonstrated that some deaf children showed difficulty in identifying disgust in facial expressions and producing the expression with a verbal label as a prompt. If the visual representation is not recognised, or misinterpreted, then imitation and correct identification (potentially via 'emotion contagion'; Atkinson & Adolph, 2002) both cannot occur.

With only a difficulty in imitating disgust, the results are encouraging for deaf children, suggesting that the ability to perform this more primitive form of mind reading is intact. Pfeifer et al. (2008) suggested that overt mimicry is an important social skill in being able to give a non-verbal response to another individual to indicate that their emotional state has been understood. First the emotional state needs to be recognised and then being able to imitate a response allows an individual to respond empathically e.g. to respond with concern when someone is crying involves a certain degree of a subtle imitation of the other person's emotion state.

Pfiefer et al. (2008) draws attention to the importance of the role of overt mimicry, yet what remains unanswered is whether deaf children spontaneously mimic emotions, given that in everyday life mimicry occurs rapidly and without effort. Children with ASD have been found to be impaired on spontaneous but not voluntary mimicry of emotion expressions (McIntosh, Reichemann-Decker, Oberman et al., 2009; Winkielman & Wilbarger, 2006). It has been suggested that mimicry is linked to a prefrontal 'mirror circuit' where neurons discharge when a similar action is executed and observed (Rizzolatti, Fadiga, Fogassi & Gallese, 2002). If deaf children had a spontaneous mimicry deficit and emotion contagion did not naturally occur, this could impact the development of inter-subjectivity that is necessary for understanding others' minds and social learning and contribute to difficulties in performance on social-cognitive ToM tasks (Meltzoff & Gopnik, 1993).

Yet the level of expressiveness displayed by the deaf children and clarity of their production of emotions suggests that this is an unlikely explanation in comparison to children with ASD who have been shown to produce significantly odder facial expressions of emotion than their typical peers (Volker et al., 2009) and for whom emotion deficits are a characteristic of the clinical descriptions of the disorder (Kanner, 1943). Importantly, deaf children were rated as producing more intense expressions of emotions by the adult raters as hypothesised and in parallel with Studies 4a and 4b, with the exception of disgust, suggesting a higher level of expressiveness. Difficulty in imitating disgust is more likely to be related to having fewer opportunities to discuss this emotion.

Summary of Study 4a-c

These are the first emotion production studies investigating voluntary encoding abilities of deaf children. With the exception of disgust, deaf children were rated by adult decoders as being overall more accurately at producing recognisable emotion expressions of greater intensity. Deaf children also showed a parallel performance in the imitation of dynamic human facial expressions. These findings need to be confirmed by testing a wider sample of deaf children, however a key role for the socialisation of emotion is indicated: it appears that clarity of emotion expression is important to deaf children's display rules (Goldstein et al., 2000); with a delay in the development of the concept of disgust, deaf children were able to encode the emotion when provided by the scaffold of a contextual story, yet it was more challenging to imitate or encode based upon a verbal label.

Chapter Seven

Study five: Reducing the visual attentional demands of the false belief task

Overview

This chapter presents a study on deaf children's social-cognitive ToM as measured by a battery of first and second order false belief tasks. Both a CA matched control group and a younger group of 'preschool aged' hearing children were compared to a group of deaf children born to hearing parents. Efforts were made to remove the additional attentional demands of an interpreter by producing pre-recorded video-clips of the tasks enacted by a hearing native signer in a choice of BSL, SSE or English. There was no difference in performance between the deaf and young hearing children, but the deaf children performed significantly worse at the unexpected content and second order false belief tasks than their CA-matched controls. These findings imply a delay rather than a deficit, likely to be related to delays in language and reduced opportunities to overhear conversations about mental states.

Introduction

The studies presented in this thesis have demonstrated that deaf children's emotion processing, while subject to some delays attributed to a reduced opportunity to converse about emotions, parallels that of hearing children. This chapter presents a study examining another important area of social cognition in which deaf children of hearing parents have displayed delays: social-cognitive ToM as measured by the ‘*false belief task’* (e.g. Peterson, 1995; Schick et al., 2007). There is little doubt that this ability is to some extent linked to language, but whether this is due to language ability (Harris, Rosnay & Pons, 2005), opportunities to discuss emotions and mental states, or as a result of the language and attentional demands of tasks measuring ToM, remains to be clarified (Bloom & German, 2000).

ToM is the cognitive ability that enables an individual to understand human behaviour and accurately interpret social situations by attributing mental states, which includes beliefs, desires, intentions and emotions (Remmel & Peters, 2008). Central to the development of a social-cognitive ToM is the capacity to understand ‘false’ beliefs – essentially, mistaken beliefs about situations - an ability typically developing children acquire between 4 and 5 years of age (Wellman et al., 2001). This aspect of ToM has been termed *‘social-cognitive’* as it appears to relate to other cognitive abilities such as memory, and in particular, language (Roth & Leslie, 1998; Tager-Flusberg & Sullivan, 2000).

In the standard false belief task – the litmus test of social cognitive ToM - the child is told a story in which the central character holds a mistaken belief regarding the location of an object (e.g. the Sally Ann marble task: Baron Cohen et al., 1995) or the content of a container (e.g. the Smartie’s task, Perner et al., 1987). As the story unfolds, the child being tested becomes aware of events that the main character does not witness. In the unexpected contents task, a second character moves an object from its initial location when the main protagonist is absent. The child is then asked where the main character will look for the object. To pass this task, the child must hold in mind that the character does not know that the object has been moved. While most 5 year olds can easily differentiate their own view from that of the main protagonist in the story, typically developing children aged 3 and younger do not understand that the this character will act upon their mistaken belief rather than according to the child's own knowledge (Wellman & Liu, 2004).

Beyond this age, children begin to extend their understanding to grasp the concept of multiple perspectives and appreciate that two people can interpret the same situation differently (Selman, 1980). By around age seven, a 'second-order' false belief task is passed by typically developed children, requiring the attribution of a first-order belief (Person A thinks X) to another person (Person B thinks "Person A thinks X") (Baron-Cohen, 1989). The original version of this task, the "ice cream task" (Perner & Wimmer, 1985), involves a situation in which a boy ("John") knows that an ice cream van has left the park to go to the school, but he believes that a girl ("Mary") does not know this. The girl did in fact did see the ice-cream van on its way to the school, as it passed by her house when the boy was elsewhere. The boy goes to the park expecting to find the girl because he does not know she knows the van is at the school. In order to pass this task the child must understand that the knowledge of the van's location was acquired by the boy and girl at different times, and he or she must differentiate between factual reality and the knowledge of each character (Perner & Wimmer, 1985).

To date, research has focused on first order false belief tasks in deaf children. The vast majority (more than 90%) of deaf children are born to hearing parents, and have typically demonstrated, at best, a delay in false belief understanding (de Villiers & de Villiers, 2001; Peterson, 2002, 2004; Peterson & Siegal, 1995, 2000, 2004; Schick, et al., 2007). In one of the first studies, Peterson and Siegal (1998) found that in middle childhood, between the ages of 8 and 13, deaf children performed poorly on the first order false belief task. Yet these children were able to perform with success on the procedurally similar false photograph task, suggesting that that a general problem with meta-representation is not the cause.

Extending these results to include a wider battery of tests, Peterson and Siegal (1999) found that the performance of late signing deaf children of hearing parents was impaired relative to hearing controls, native signing and oral deaf children, and paralleled that of a group of autistic children. Peterson and Siegal (1995) proposed 'the conversational hypothesis', positing that it is the dearth in experience of conversing about mental states that leads to difficulty in acquiring ToM for both late signing deaf and autistic children, albeit for different reasons. A positive correlation with age was suggestive of a delay rather than a deficit in ToM, however a comparison with typically developed children is problematic given that the mean age of the control group was five years younger than the group of deaf children. Subsequent studies by Peterson and colleagues similarly found that late signing, and also oral, deaf children were outperformed by pre-schoolers (Peterson, 2002, 2004). The difference between the oral deaf children in these latter studies in comparison to Peterson (1999) is that the children were severe-profoundly rather than moderately deaf, suggesting the children in the earlier study were more likely to have access to early communication.

In contrast, studies have shown that deaf signing children of deaf parents have performed in parallel or better than hearing children on the false belief task (Courtin, 2000; Courtin & Melot, 2005). Courtin (2000) asserts that the grammatical structure of sign language usage promotes the visual perspective taking and structure necessary to represent a point-of-view that is needed to pass false belief tasks. Many late-signing children's families have limited or no skills in sign language, so it is plausible that this reduced opportunity and faculty to converse about mental states leads to such mind-reading difficulties (Vaccari & Marschark, 1997). Given the link between joint attention and ToM in pre-schoolers (Nelson et al., 2008) and that some late-signing and some oral deaf children display less occurrences of joint attention than deaf children and hearing children, it is an interesting proposition that sign language may facilitate communicative experiences that result in mental state understanding. Yet sign language ability was not considered in these studies as no standardised measure of French sign language existed. Not including a language measure relies on the assumption that deaf parents communicate well in sign language, which is not necessarily always the case (Tomasuolo, Valeri, Di Renzo, Pasqualetti & Volterra, 2013; Van Den Bogerede, 2000).

A later study by Schick et al. (2007) demonstrated that the performance by late signing and oral children was not a poor as earlier studies had indicated. Schick et al. compared deaf children of different backgrounds between the ages of 4 and 7 with hearing children aged 4 to 6 years (7 year olds were excluded due to previous studies indicating likely ceiling effects). Schick et al. (2007) found that while oral and late-signing deaf children's overall performance was poorer than that of native signers and hearing children, by age 7 the oral children's performance on the low verbal false belief tasks was equivalent to the comparison groups' and the late-signing deaf children were comparable on both the low verbal *and* verbal false belief tasks. These results reveal a lesser delay than earlier studies suggest.

One important distinction between Schick et al. (2007) and the majority of other studies is the experimenter, Schick, is a CODA meaning that she has a native level of sign language (ASL) and can also communicate equally well with signing and oral deaf children. Many other studies investigating deaf children's false belief tasks have relied upon an interpreter, which adds an additional demand on children's attention as switching back and forth between the interpreter and experimenter is required. Peterson and colleagues are hearing and thus an interpreter was used to translate the instructions into sign language (e.g. Peterson, 2002, 2004, 2009; Peterson & Siegal, 1995, 1999; Peterson & Slaughter, 2006), and Courtin (2000) is Deaf and so task instructions were required to be translated into spoken French by an assistant for oral deaf children.

Studies comparing oral deaf children with different types of hearing amplification have revealed inconsistent results. While Peterson's (2004) study revealed a delay of between 3 to 5 years in ToM acquisition of deaf children with CIs, studies by Peters and colleagues found only marginal delays in children between 3 and 12 years (Peters et al., 2009; Remmel & Peters, 2008). In a more recent study, Ziv et al. (2013) found that younger deaf Israeli children (aged 5 – 7) with CIs' performance was higher than previously found and paralleled hearing children's performance. Yet there is much variability in false belief performance between children with CIs. Peters et al.'s (2009) study revealed positive correlations between false belief scores and duration of implantation. In addition, Ziv et al. (2013) noted that a number of children with CIs who performed poorly also had low verbal ability. The heterogeneity of deaf oral children's communication and linguistic background warrants caution in directly linking levels of performance with cochlear implantation.

Given the undoubtable link to language it may seem surprising that only a handful of studies have considered the language or signing ability of deaf children. Yet there is difficulty in standardising measures for deaf populations. Many deaf children use a combination of sign (ASL/BSL) and oral English in communication, and there is difficulty in assessing these languages simultaneously as the languages do not always directly correspond in terms of difficulty. Therefore a signed response may be ambiguous and could purely reflect a guess (Schick et al., 2007). While some researchers have taken only subjective measures of language ability such as class teacher reports (e.g. Peterson & Siegal, 1999), others have attempted to use more stringent measures like the Peabody Picture Vocabulary Test (PPVT: Dunn & Dunn, 1997) (e.g. Peterson, Wellman & Liu, 2005). However, these tasks have not been standardized with a deaf population and so require a minimum level of hearing to be valid (Prezbindowski & Lederberg, 2003). A receptive language measure standardised for oral deaf children currently does not exist.

Similarly, very few studies have examined sign language abilities and performance on the false belief task. Meristo, Falkman, Hjelmquist and Tedoldi (2007) adapted the BSL receptive language test into Italian sign language and found no link between sign language ability and scores on tests measuring ToM reasoning. However, as highlighted by Haug and Mann (2008), there are difficulties in translating sign language tests from one language to another; while cultural differences can be relatively easy to accommodate (e.g. by changing images to fit the target culture), language related changes require more significant modifications, bringing into question how well the psychometric properties of these measures translate.

In a comprehensive study, Schick et al. (2007) found that vocabulary, as measured by the standardised receptive ASL vocabulary test (Schick, 1997), significantly predicted ToM performance. Similarly, Jackson (2001) found that BSL receptive language scores predicted performance on false belief tests of late signing deaf children, as did vocabulary predict oral deaf and hearing children's performance. Other links between false belief and language have also been proposed. Schick et al. (2007) additionally found that both signing and oral deaf children's understanding of sentence complementation predicted performance on ToM tasks, as de Villers and de Villiers (2001) had previously found with only oral deaf children. Others argue that pragmatic, conversational abilities (Meristo et al., 2007) or mental state vocabulary is important. For example, Moeller and Schick's (2006) study provided evidence for a link between mother's mental state talk and deaf children's ToM. It is difficult to currently pinpoint the exact role of language.

Equally, it is important to consider that assessing deaf children's ToM abilities is challenging due to the inherent impact language has on the development of the concept. As hearing impaired children are documented to have lower levels of language comprehension (Marschark & Wauters, 2008), it is possible that the difficulty lies in pragmatics due to the verbal nature of the task. Indeed, some previous studies have included those children who fail control tasks: a clear indication that the task was not understood (Steeds, Rowe & Dowker, 1997; Jackson, 2001).

Attempts have been made to overcome the language barrier presented by ToM tasks by adopting non-verbal (de Villiers & de Villiers, 2000; Figueras-Costa & Harris, 2001) or pictorial (Woolfe et al., 2002) versions of false belief tasks, so to make them more accessible to deaf children. De Villiers and de Villiers (2000) found that oral deaf children performed no better on a non-verbal sticker-hiding ToM task than the standard tasks. In another study using a pictorial task, Woolfe et al. (2002) found that late-signing deaf children showed deficits in ToM understanding, even when controlling for syntax ability, spatial ability and executive functioning. However, Woolfe et al.'s (2002) task is arguably not entirely non-verbal and was administered in BSL to late-signing deaf children, some of whom scored poorly on their BSL receptive language tests. In addition, difficulties arise when using pictorial and linguistic tasks with deaf signing children because of the absence of pragmatic cues that can be gleaned from facial expressions (Napoli & Sutton-Spence, 2010).

As many deaf children either have problems with learning BSL or use English to communicate, the possibility remains that difficulty with ToM tasks is due to problems with comprehension. In particular, oral deaf children are heavily reliant on lip-reading, which is challenging to follow both with BSL and by watching a speaker's lip patterns alone, especially when that person is unfamiliar. Importantly, since the majority of deaf children grow up in hearing families and attend mainstream schools, BSL is not often the primary method of communication that is adopted. With hearing amplification - increasingly, the use of CIs - many deaf children rely on lip-reading in addition to residual hearing to communicate in a hearing environment, often accompanied by signed English i.e. SSE. SSE offers deaf children with poorer signing skills or who are predominantly oral, additional communication cues.

Study 5

This present study aims to address a number of issues outlined in the above literature review in assessing deaf children of hearing parents in their false belief understanding. Previous research has been variable in its procedural methods and control measures employed. The majority of tasks have been carried out with the use of an interpreter (e.g. Peterson, 2002, 2004, 2009; Peterson & Slaughter, 2006; Peterson & Siegal, 1995, 1999), or an experimenter who is neither a native signer or fluent in the relevant sign language (e.g. BSL: Jackson, 2001). The problem an interpreter poses is a divide in attention between the experimenter enacting the false belief task and the interpreter, which is visually strenuous particularly for late-signing deaf children who sign less confidently. Given the evidence that suggests that hearing-impaired children have significant deficits in visual selective attention in comparison to CA-matched peers (Dye, Hauser & Bavelier, 2008), the added task demand of switching attention between the experimenter and interpreter could pose an unfair disadvantage.

Schick et al.'s (2007) study overcame the added task demand placed by using interpreters as the experimenter was a native signer of ASL. The ToM tasks in this study were similarly presented by a CODA, fluent in both BSL and English, to maintain one focus and maximise understanding. In addition, the aim was to overcome the language demands by presenting a battery of ToM tasks in SSE in addition to BSL and English. The inclusion of SSE provided late-signing or oral deaf children with the option of viewing the task in the language they communicate in, or with additional cues instead of relying solely on lip-reading. Pre-recording each task allowed greater control over administration; each participant viewed the same version of the task to avoid variation between participants and disparity from the use of multiple experimenters (e.g. Schick et al., 2007) - an important consideration due to the inherently social and emotional nature of ToM tasks. The battery of tasks also included a second-order false belief task that, to our knowledge, has only been attempted once before with deaf children (Jackson, 2001).

A second aim was to control more carefully for language ability of the deaf children. As language is clearly implicated in the development of ToM is it vital to obtain an objective measure. In this study, the BSL receptive language (Herman et al., 1999) measure was utilised with those deaf children who used sign language. As many of the oral deaf children relied on lip-reading, the Craig's Revised Lip-reading Inventory (Updike et al., 1992) was also administered to control for task failure resulting from a lack of understanding.

In sum, the present study tested a group of deaf children who represent the majority of deaf children in the UK: deaf children of hearing parents who all communicate orally with some sign language. To control task administration, the tasks were presented in pre-recorded video clips conducted by a native signer. A choice of language – BSL, SSE or English - was given to account for potential different communication preferences. The children were compared to two control groups of hearing children: one group matched for non-verbal ability and CA (older hearing) and a second 'age appropriate' group for the false belief task (younger hearing i.e. 4 and 5 year olds). Based on previous findings it was predicted that:

Hypothesis one: deaf children would perform similarly to the younger group of hearing children but may be delayed in comparison to the older group of hearing children on the first order false belief tasks.

Hypothesis two: on the second order false belief task, the older hearing children would perform better than the younger hearing children and, based on the findings of Jackson (2001), the deaf children. Second order false belief understanding has been shown to develop later than first order belief understanding (Hughes et al., 2000; Miller, 2009; Perner & Wimmer, 1985).

Hypothesis three: general language ability (BSL receptive skills/BPVS scores) would predict deaf children and younger hearing children's ToM task performance. Also vocabulary was predicted to relate to better performance on the second order false belief task for older children given that language ability has been shown to predict typically developing children's performance in previous studies (Filippova & Astington, 2008; Hasselhorn, Mähler & Grube, 2005; Miller, 2009).

Method

Participants

Seventy-three children participated in the study. The deaf group consisted of 16 girls and 11 boys aged between 6 years 7 months and 12 years 1 month (mean CA = 9 years 0 months, *SD* = 1 years 6 months). Their non-verbal IQ scores ranged from 70 to 125 (Table 39). The criterion for selection of deaf children was: 1) the presence of either severe or profound pre-lingual hearing loss. Eleven children were profoundly deaf (hearing loss > 90 db) and 16 children were moderate-severely deaf (hearing loss > 60 db); 2) CA between 6-12 years: the age at which both first and second order belief tasks are usually passed in a hearing sample; 3) exposure to oral language; 4) no known learning disabilities or concomitant disorders such as attention deficit or autism; and 5) parents who were both hearing.

Twelve of the children had one or more parents who had some knowledge of sign, and for the other 15 children there was no member of the family identified who could sign. Of the 12 children who had a family member who could sign, nine of these children had one family member and three had at least two members of the family who could sign. However, only three parents in this sample of children were proficient at BSL signing (BSL Level 2 or above; minimum requirement for school teachers). All children received auditory amplification: 14 wore CIs and 13 wore HAs. Each participant attended one of five mainstream schools with special units for hearing impaired children. All children were oral in their communication preference, using some SSE or BSL, although none were native signers.

Two controls groups were included in the study, and they were categorized as an older group of children and a younger group. The older group of controls included 23 children with no hearing loss aged between 6 years 1 month to 11 years 6 months and were matched with the deaf children on gender (15 female), CA (*M* = 8 years 8 months, *SD* = 1 year 6 months) and non-verbal IQ . Table 39 displays mean CA, non-verbal ability and language scores for deaf and hearing older and younger control groups. Independent t-tests confirmed no significant difference in non-verbal IQ between the deaf and older hearing children, t (48) =-.09, p=.93, or CA, t (48) = .77, p =.45. The younger group consisted of 23 children (12 female) with no hearing loss were aged between 4 years 5 month and 5 years 9 months (*M* = 5 years 2 months, *SD*= 4 months). This group was purposefully included as the children were all at the age at which the first order belief tasks would be expected to be passed, but not the second order belief tasks.

Table 39. CA, *Non-verbal IQ, Verbal IQ and Language Measure Mean Scores and SDs for Deaf and Older Hearing and Younger Hearing Control Groups (Study 5)*

	Children		
	Deaf	Hearing older	Hearing younger
CA (yrs.mnths)	9.0 (1.6)	8.8 (1.6)	5.2 (.4)
Non-Verbal IQ	97.26 (15.33)	97.61 (12.51)	105.43 (11.86)
Verbal IQ (BPVS)		104.0 (13.28)	103.57 (11.47)
Lip Reading	105.48 (10.6)		
BSL Receptive	96.23 (13.79) (*N*= 22)		

Note: Standard deviations are in parenthesis

Materials

Standard false belief tasks: Two unseen change-in-location tasks were presented. The first task was a slightly modified version of Baron-Cohen et al.'s (1985) version of Wimmer and Perner's (1983) 'Sally-Ann false-belief' task: in the original paradigm, it was necessary to finger spell the name of the dolls, which places further demands on both the children's attention span and memory (Peterson and Siegal, 1995). A boy, therefore, replaced a second female character (Peterson & Siegal, 1995; Steeds et al., 1997). The child being tested was initially introduced to the characters and asked which doll was the girl and which was the boy (naming question). The task began with the girl hiding a marble in a basket and then leaving the scene. Once she departed, the boy appeared and moved the marble from the basket and put it in his own box. When the girl returned, the child was asked, "Where will the girl look for the marble?" followed by two control questions:

"Where is the marble now?" (reality) and "Where did the girl put the marble in the beginning?" (memory). In order to pass the task, the children needed to correctly answer both the test question and the control questions.

In the second trial of the false belief transfer task –' Hidden Cakes' - a boy placed a tray of cakes (plastic) in a green cupboard to cool down, and then went out to play. A second character, a girl, removed the cakes from the green cupboard and placed them in the blue cupboard. When the boy returned and the child was asked the belief question, *"Where will the boy look for the cakes?"* This was followed by the same two control questions.

The misleading-container tasks were based on the Smarties task described by Perner, Frith, Leslie, and Lekam (1989) and presented in two trials. In this study, the first trial involved a misleading tube of sweets that instead contained a red crayon. The sweets were the favourite of the hungry doll presented in the scene. Once the unexpected object was revealed to the participant, they were asked what the hungry doll initially believed the closed tube of sweets to contain, and what their initial belief had been. In the second trial, a cereal box was used, which actually contained two pencils.

Second order false belief task: 'Ice-cream story.' The second order false belief task was based on the ice-cream story used by Perner and Wimmer (1985). The story involved three locations: a park (where the ice-cream van was located originally), the girl's house and a school (the new location of the ice-cream van). The ice-cream van and the girl's house were used as props, as well as puppets representing the four characters: the girl, the boy, the ice-cream man and the mother. To be able to pass the task, the child needed to understand what two people were thinking sequentially: the boy had a false belief about what the girl thought because an element of the story had not been seen. The actor narrated the task and asked a series of probe and control questions to ensure the key elements and sequences of the story had been understood and remembered. The children's responses were recorded in written format. Feedback and correction was given before continuing onto the next section of the narrative. The second-order ignorance question was then asked as the first test question and no feedback was given. Following a memory aid, the story ended with two open-ended test questions: the second-order false-belief question and justification (Sullivan, Zaitchik and Tager-Flusberg, 1994) (see Appendix H for all story scripts).

Procedure and design

All the children were tested on a battery of tasks that included four standard first order false belief tasks, (two unseen change-in-location tasks, and two unexpected contents tasks), and one second order false belief task. Each child was tested individually in a quiet vacant classroom in their school in one session lasting approximately 30 minutes.

The tasks were presented using a pre-recorded ToM script. Each of the false belief stories was presented by a hearing, native signer. The actor both animated puppets and props and narrated the stories, so to maintain one focus rather than dividing the children's attention between an experimenter and an interpreter. Three versions of each task were produced in BSL, SSE and spoken English to account for the first language of all participants involved in this study. Twenty-one deaf children chose to view the task in SSE and two in BSL. The stories were pre-recorded on a digital camcorder, and a clip was created for each ToM task (see Appendix I for an example story board). All of the clips were validated by two deaf adults (both at BSL Level 3).

The children were seated in front of a computer screen. The order in which the four first-order false-belief tasks were presented was counterbalanced, followed by the presentation of the second order false belief task. The answer to the children's questions (signed or verbal response) was recorded by the experimenter. The children were given a short break before continuing onto the second-order false belief task if necessary. Although the experimenter was competent in BSL, a teaching assistant competent in both sign languages (BSL; SSE), accompanied the deaf children to ensure accuracy of answers recorded.

False belief task scoring: Children were given one point if they correctly answered *"where will X look?"* in response to the changed-location tasks and one point if they correctly answered their *own belief* and the *other's belief* questions on the unexpected-contents tasks, giving the highest possible score of two for each task. Six deaf participants were excluded from this study due to failure to pass the control questions. As the standard false belief tasks involve open questions that require a child to respond depending on their own belief, chance is deemed to be zero (Schick et al., 2007). Participants were awarded one point if they correctly answered the second-order false belief task.

Results

Overall Performance

The data was not normally distributed and there was a lack of homogeneity of variance, so non-parametric test were carried out. Table 40 displays the means and SDs scores of the unexpected location, unexpected content and second order false belief tasks for the three groups. Kruskall Wallis tests were conducted comparing the three groups of children – deaf, hearing younger, hearing older – on each of the (first order) false belief tasks. No significant difference was found between the groups' performance on the unexpected location trials (H (2) = 4.23, p = .12, η^2 = .06). Group differences did, however, emerge in performance on the unexpected content trials (H (2) = 73) = 9.08, p = .01, η^2 =.13) and the second order false belief task (H (2) = 30.14, p <.005, η^2 =.42).

Post hoc Mann Whitney U tests (with Bonferroni corrections of p <.02) testing differences between groups on the unexpected content task showed that the older hearing children performed significantly better than the deaf children (U = 206.0, z = -2.81, p = .005, r = .21) and the younger hearing children (U = 170.5, z = -2.87, p = .004, r = .42), but there was no significant difference between the younger hearing children and the deaf group children (U = 310, z = -.01, p = .99, r = .001).

Figure 5 shows that a much greater percentage of older hearing children (69.5%) passed the second order false belief tasks than both the deaf children (3.7%; one child) and the hearing younger children (13%; three children). Chi square tests of independence confirmed that these differences were significant (deaf: χ^2 = 24.01, df = 1, p <.001, Φ = .69; hearing young: χ^2 = 30.56, df = 1, p <.001, Φ .82). There was no significant difference between the number deaf and hearing young children passing the second order false belief task (χ^2 = 1.47, df = 1, p = .22, Φ = .17).

These results suggest that deaf children's performance on the unexpected contents and second order false belief tasks lagged behind the CA matched hearing control group, but paralleled that of the younger group of hearing children within the age range that is typical for passing the false belief task. This is illustrated in Figure 5, which shows the percentage of children who passed both trials on the two first order false belief tasks, and the percentage of children who passed the second order false belief task. A within subject analysis (Wilcoxon) of deaf children's unexpected content and unexpected location task scores found no significant difference (z = -1.08, p =.28, r = .21), suggesting that the unexpected contents task was not more difficult than the unexpected location task for the deaf group children.

Table 40. *Mean Performance of Deaf and Hearing Children on the False Belief Tasks*

	Mean rating		
Task	Deaf	Hearing younger	Hearing Older
Unexpected location	1.59 (.69)	1.35 (.93)	1.87 (.34)
Unexpected content	1.41 (.84)	1.43 (.79)	1.96 (.21)
Second order	.04 (.19)	.13 (.34)	.70 (.47)

Note. SDs in parenthesis

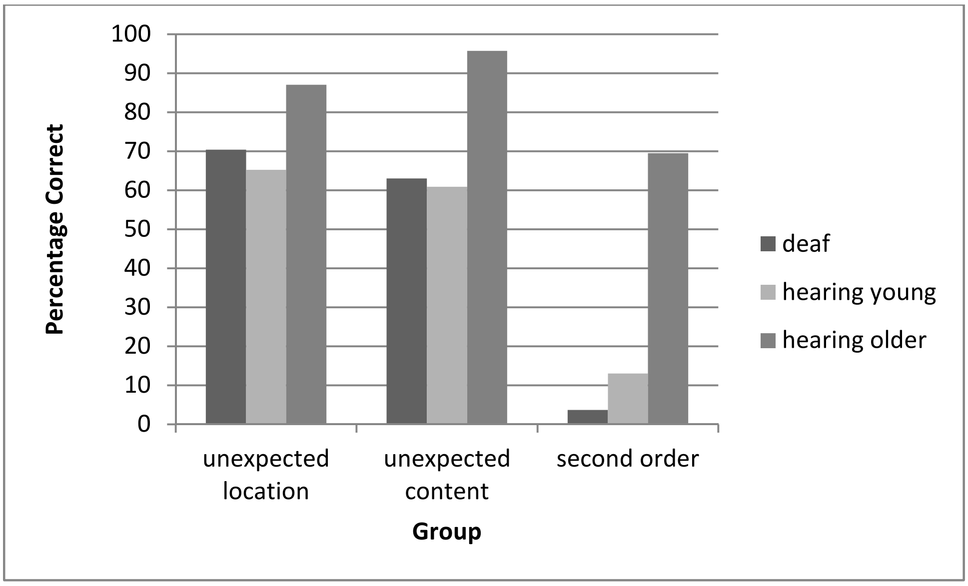


Figure 5. Percentage of deaf, young hearing and older hearing children passing both trials of first order tasks and the second order task

Factors predicting false belief performance

Further analysis was conducted to investigate the relationship between CA, non-verbal IQ, verbal ability (BSL receptive language for deaf children and BPVS for hearing children) and performance on each of the false belief tasks. For the deaf children, lip-reading, type of hearing amplification (coded as 0 = CI, 1 = HA) and signing ability of the parents (coded as 0 = no experience, and 1 = at least one of the parents can sign) were also included for the sample of deaf children. Mean and SDs of scores for subgroups deaf of children grouped on hearing amplification and whether a member of their family signed are displayed in Table 41.

A regression analysis revealed that for deaf children's scores on the unexpected location false belief task, $R^2 = .38$, $F = 1.42$, $MSE = .57$, $p = .27$, lip reading ability score was the only significant predictor of performance of the group of deaf children ($\beta = .54$, $p = .04$); CA ($\beta = .43$, $p = .11$), BSL receptive language ($\beta =$

-.30, *p* =.26), family's level of sign language (β = -.19, *p* =.51), type of hearing amplification (β = -.20, *p* =.49) and non-verbal ability (β = .17, *p* =.48) were not significant predictors. For the older group of hearing children, none of the factors significantly predicted performance (R^2= .19, F = 1.48, MSE = .11, *p* = .25; CA: β = .47, *p* =.07; non-verbal ability: β = -.03, *p* =.91; BPVS: β = .18, *p* =.44). Similarly, none of the factors predicted performance of the younger hearing children's performance on the unexpected change of location false belief task (R^2= .27, F = 2.36, MSE = .74, *p* = .10; CA: β = .26, *p* =.26; β = .23, *p* =.33; non-verbal ability: β = .32, *p* =.17).

For the unexpected content task, BSL receptive score was a positive and significant predictor of deaf children's performance (R^2= .55, F = 2.84, MSE = 1.21, *p* = .05; BSL receptive: β = .47, *p* =.05) and lip-reading ability marginally predicted performance (β = .37, *p* =.08), but CA (β = -.14, *p* =.52), family's level of sign language (β = .18, *p* =.48), type of hearing amplification (β = -.05, *p* =.85) and nonverbal ability (β = -.31, *p* =.15) were non-significant. None of the factors significantly predicted the older hearing children's performance (R^2= .09, F = .65, MSE = .05, *p* = .59; CA: β = -.03, *p* =.98; non-verbal ability: β = .17, *p* =.53; BPVS: β = -.33, *p* =.20). Verbal ability was found to be a strong, positive predictor of the younger hearing group of children's performance on the unexpected content task (R^2= .39, F = 3.96, MSE = .44, *p* = .02; BPVS: β = .67, *p* =.004), and both CA (β = .40, *p* =.07) and non-verbal ability (β = -.44, *p* =.052) were marginal predictors.

Due to floor effects in both the deaf and younger hearing children's scores on the second order false belief task, it was not possible to examine factors predicting the performance of these groups of children. For the older hearing children's performance on this task (R^2= .21, F = 1.72, MSE = .20, *p* = .20), CA was found to be a significant predictor (β = .52, *p* =.04), whereas non-verbal ability (β = .20, *p* =.42) and verbal ability were not (β = .00, *p* =.99).

Finally, the deaf children were compared on their first order false belief performance according to level of deafness – profound or moderate-severe (mean and SDs of scores are displayed in Table 41). Mann Whitney U tests showed no significant difference between moderate-severely deaf and profoundly deaf children on either the unexpected location tasks, U = 68, z = -1.23, p = .34, r = .18, or the unexpected content tasks, U = 75.5, z =-.72, p =.54, r =.11.

Table 41. *Mean and SDs of Scores on Unexpected Content and Unexpected Location ToM tasks for Subgroups of Deaf Children (Study 5) (Divided by hearing amplification, level of deafness, communication preference, and whether have signing family members)*

	CI or HA		Level of deafness		Signing family member	
	CI (*N* = 14)	HA (*N*= 13)	Severe (*N* = 16)	Profound (*N* = 11)	Yes (*N* = 12)	No (N = 14)
Unexpected location	1.57 (.65)	1.62 (.77)	1.67 (.70)	1.45 (.69)	1.5 (.80)	1.64 (.63)
Unexpected content	1.43 (.85)	1.38 (.87)	1.5 (.82)	1.27 (.90)	1.17 (.94)	1.64 (.74)

Discussion

An aim of the current study was to control more carefully for the language demands of the ToM tasks. Administration was controlled by employing a native signer (a CODA) to conduct the tasks, which were pre-recorded and presented as film clips in a choice of BSL, SSE or English. The majority of deaf children selected to view the tasks in SSE demonstrating the usefulness of signed English as an additional aid to understanding, even for predominately oral deaf children.

As predicted by hypothesis one, the deaf children's performance on the first order false belief tasks – both the unexpected location and unexpected content trials - paralleled the younger deaf children. As expected, the older group of hearing children performed at near ceiling level on the first order tasks. While the deaf children were significantly worse than the chronological CA matched controls (older hearing) at the unexpected contents task, there was no significant difference between the groups on the unexpected location task. These results are similar to those found by Schick et al. (2007), suggesting a delay rather than a deficit in social-cognitive ToM. No finding of a delay in comparison to preschool age children contrasted the results found in several previous studies involving late signing and oral deaf children (Peterson, 2002, 2004; Peterson & Siegal, 1995, 1998). The more favourable results than those found in studies involving interpreters to administer the false belief tasks emphasise the advantage of the employment of a CODA to administer false belief tasks to maximise clarity, understanding and minimise demands on visual attention.

Despite the better performance of the deaf children of hearing parents in this study in comparison to some previous studies, a delay was nevertheless evident. No advantage of CIs was found in comparison to HA, neither was a difference found between moderate-severely deaf and profoundly deaf children. The sub-group of deaf CI wearers was too small to explore the age of implantation, which has previously shown that early implantation results in better ToM performance (Remmels & Peters, 2009). This nevertheless suggests that potential for greater auditory access is not directly resulting in better performance on first order false belief tasks for these deaf children. Interestingly, there was no significant relationship with age and performance within the deaf group. Rather, the great performance variability within this group likely reflects the differences in communication experiences and language ability.

Because the ToM delay in late-signing and oral deaf children has been linked to language, a second aim of this study was to control for language ability. Where children who failed control tasks have previously been included (Jackson, 2001; Steeds et al., 1997), only children who passed the control questions were included in this study. Many previous studies with deaf children have included only a subjective measure (e.g. Peterson & Siegal, 1999) of oral English (e.g. Peterson et al., 2005; Prezbindowski & Lederberg, 2003) or sign language measures (Meristro et al., 2007) that were not standardised for use with deaf populations. The deaf children in this study were tested on both standardised BSL receptive language test (Herman et al., 1999) and the Craig's lip-reading inventory (Updike et al., 1992).

Although communicating with a mixture of sign language and English (SSE), the late signing deaf participants scored within the average range on the BSL receptive language test and also within the average range on the Craig's lip-reading inventory (Updike et al., 1992). Notably, the deaf children in this study scored significantly higher on the BSL receptive test than late-signing and oral children in previous studies (Jackson, 2001; Woolfe, et al., 2002). As predicted, a significant positive relationship was found between performance on the unexpected contents task and the false belief task, but this relationship was not a predictor of performance on the unexpected location tasks. However, a significant positive relationship between lip-reading ability and performance on the unexpected location tasks was found. In addition, lip-reading also marginally predicted performance on the unexpected contents tasks. This suggests that a good level of sign language and access to spoken language (as indicated by lip-reading) are linked to better success on false belief tasks, in line with some previous studies (Jackson, 2001; Schick et al., 2007). Consistent with these results, receptive vocabulary (as measured by the BPVS) also predicted the younger hearing children's unexpected contents task performance.

Previous research has focused on deaf children's understanding of first order false belief tasks and little attention has been given to the attribution of second order beliefs – that is, the attribution of the belief of one character to another, hence demonstrating an appreciation of multiple perspectives (Baron-Cohen, 1989). The third prediction that the older hearing children would outperform both the younger and older hearing children on the more complex second order false belief task was confirmed by the results of this study. In agreement with previous research with typically developing children, the older hearing children also outperformed the younger hearing children (Miller, 2009; Perner & Wimmer, 1985). It is not surprising that the younger hearing children (aged 4 and 5) performed poorly given that this ability has been shown to emerge around the age of 7. However, both the young group of hearing children and the deaf group of children's performance was subject to floor effects. In addition, the deaf children in the current study performed worse than those tested in the only other study to have previously tested deaf children's second order false belief, with only 3% passing in comparison 22% (Jackson, 2001). One difference between the current study and Jackson's (2001) study is a variance in scoring, as the justification of belief question was omitted from this earlier study; an explanation that requires a child to reflect and verbalise the reasoning process about mental states (Miller, 2009).

The older hearing children's second order false belief task with a 69% pass rate demonstrates considerably better performance. Interestingly verbal ability as measured by the BPVS did not predict the older hearing children's performance as has previously been found (Fillippova & Astington, 2008; Hasselhorn et al., 2005), but there was a significant improvement with age. If not verbal ability, what can be attributed to this improvement in performance with age, and the deaf children's inability to perform at this task? While some believe that increased social knowledge from interactions with siblings may be essential to the transition from first- to second- order false belief, others argue that the critical difference may lie in improvements in executive functions (EF e.g. working memory and inhibition) as well as language (Miller, 2009, 2012).

The specific relationship between ToM and language remains unclear (Harris et al., 2005) and this study has not attended to a number of language hypotheses of ToM. The BSL receptive language test that has been utilised does not, for instance, investigate the syntax of sentence complementation. To understand this aspect of language requires the ownership of syntactic structures including those that allow the embedding of false propositions within true statements (e.g. "the boy knows that the girl [falsely] thinks he's gone to the park.").

In addition to vocabulary, Schick et al. (2007) found this to be predictive of deaf children's ToM performance, suggesting that complements may have a role in the ability to discuss and represent mental state concepts. More recently, de Villiers and de Villiers (2012) found sentential complements task with verbs of communication the best predictor amongst language measures over and above vocabulary or general syntax. Tomasuolo et al. (2012) found that children's ability to construct and narrate a story revealed a strong relationship with ToM performance than other linguistic factors. The current study's results suggest that further research concerning more specific language abilities of deaf children is necessary given that general language ability may not be the only factor in the development of ToM.

There are also the constraints to language measures for deaf children as outlined in the introduction of this chapter. While the deaf children scored within the average range on the sign language task, it is possible that this measure did not capture the extent of their language abilities. There is a definite need for the development of language measures that are standardised for oral deaf children that can be responded to both in signed and spoken English (Haug & Mann. 2008; Schick et al., 2007).

Criticism could be cast for using the second order false belief task with deaf children due to its highly verbal nature. Interestingly, Hollebrandse, van Hout and Hendriks (2012) found that typically developing hearing 7 year old children performed better in the *verbal* than the non-verbal false belief tasks. Hollebrandse et al. (2012) suggested that language *supports* explicit reasoning about beliefs possibly assisting the cognitive system to monitor and keep in mind beliefs attributed by people to other people; in contrast, the non-verbal task did not have the questions throughout that helped to keep track of this process of reasoning. In keeping with these results, deaf children perform no better on non-verbal than verbal first order false belief tasks in a number of previous studies (de Villiers & de Villier, 2000; Figueras-Costa & Harris, 2001; Woolfe et al., 2003).

Future research could consider a non-verbal task in assessing deaf children's second order false beliefs, and be inclusive of older children to determine the age at which deaf young people are able to pass such a task. As native signing young deaf children are able to pass first order false belief tasks at a comparative age to preschool hearing children (e.g. Courtin, 2000), it is important to establish the performance of this group of children on second order false belief tasks to determine whether this pattern extends to more complex mental state understanding.

In sum, the results of Study 5 suggest that the problem does not lie with the verbal demands of the task. However, controlling administration with the use of pre-recorded stories, and reducing attentional demands by employing a native signer to narrate the stories, revealed a delay rather than a deficit in false belief understanding in deaf children in comparison to their CA-matched controls (Schick et al., 2007). Language and access to conversation is clearly implicated to be of importance in securing false belief understanding, however, these findings suggest it is unlikely to relate solely to verbal ability.

Chapter Eight:

Overall discussion and conclusions

The primary aims of this thesis were to clarify deaf children's ability in facial emotion recognition, to provide an initial investigation of emotion production in deaf children, and finally to relate these findings to the original focus of deaf social cognition research – the social-cognitive abilities in ToM as measured by the *false belief* task. This chapter draws together the experimental findings and provides a critical discussion in the context of previous research and theoretical underpinnings. Methodological strengths and weaknesses are highlighted and suggestions for future directions for research outlined. The conclusions have relevance for deaf children's social and emotional development, particularly emphasising the importance of maximising access to conversation and language.

Deaf children's emotion recognition

Prior research on deaf children's facial emotion recognition abilities is sparse and has revealed mixed findings. Some studies revealed similar emotion recognition abilities to hearing children (e.g. Hosie et al., 1998), whereas others studies have indicated poorer performance (Dyck et al., 2004), which has been linked to fewer opportunities to discuss emotions in the absence of auditory input. The first three studies of this thesis sought to clarify deaf children's facial emotion recognition abilities through the employment of more ecologically valid methods that better reflect deaf children's everyday experience of communication. Three aspects were considered: the use of real versus cartoon/synthetic faces, the role of motion and the role of intensity in deaf children's emotion recognition. First, the results of Study 1 confirmed the hypothesis that deaf children would perform poorly in comparison with hearing controls in the recognition of cartoon facial expressions of the emotions, happiness, sadness and anger, as had previously been found in studies utilising synthetic stimuli (Dyck et al., 2004; Ludlow et al., 2010; Wiefferink et al., 2013). In contrast, the performance of the recognition of real human faces paralleled that of the hearing children.

These findings suggest that the human face is a particularly important source of social and emotional information for deaf children. This social value is well established in emotion developmental literature given that typically developing infants have a tendency to pay particular attention to human faces (Nelson & Horowitz, 1987). Real human faces appear to be even more crucial for deaf people's social and linguistic communication. Eye-tracking studies have demonstrated that the human face (especially the eyes) rather than the hands is the focal fixation point during deaf communication (Muir & Richardson, 2005; Watanabe et al., 2011). Cartoon and synthetic stimuli (e.g. morphed faces) do not contain the detail of the naturally occurring features of real human faces such as skin wrinkling and bulging (Ekman et al., 2002). In addition, a potential confounding variable of this study was that the cartoon images portrayed a lesser degree of emotion intensity. While the FACS was adhered to when manipulating the cartoon stimuli to display emotion expressions, a lesser degree of intensity may have resulted due to limitations of the software. This issue was later addressed in Study 3 when investigating the impact of increasing levels of intensity on deaf children's emotion recognition in real human faces.

Second, Studies 1 and 2 addressed the issue that emotion recognition studies to date have utilised static images portraying facial expressions of emotion (e.g.

Hosie et al., 1998; Ludlow et al., 2010; Ziv et al., 2013). The importance of motion and therefore the use of dynamic stimuli has recently been acknowledged by those studying emotion recognition in both typically developed (e.g. Montirosso et al., 2010; Nelson & Russell, 2011) and other clinical populations (e.g. ASD: Gepner, Deruelle & Grynfeltt, 2001), yet the studies presented in this thesis were the first to investigate the effect of motion on deaf children's emotion identification in real human faces. Motion is an important consideration given the reality that emotions expressions are dynamic in nature. For this reason, dynamic displays are important for ecological validity, but also due to the differing neural networks evoked when viewing dynamic images in comparison to those activated when viewing static images: dynamic images have been shown to activate distinctly social areas (superior temporal sulci) (Kessler et al., 2011; Kilts et al., 2003; Krumhuber et al., 2013).

It was hypothesised that motion may be of particular importance to emotion recognition in deaf children for a number of reasons. Motion cues have been identified as an important factor in other areas of deaf communication: sign language involves hand movements to decipher linguistic communication and mark grammatical distinctions and, without auditory input, verbal communication relies on the movement of lip-patterns (Corina et al., 2007; Haxby et al., 2002). There is evidence to suggest that deaf people have a greater sensitivity to motion in the absence of hearing - increased neurological activation has been displayed when detecting motion in velocity changes in peripheral stimuli (Armstrong et al., 2002; Stevens & Neville, 2006). In Study 1, as predicted, motion enhanced both the deaf and hearing children's emotion recognition of the cartoon faces. This is consistent with previous research using synthetic stimuli (Bould & Morris, 2008; Kätsyri & Sams, 2008; Wehrle et al., 2000). It has been suggested that as cartoons have fewer clear features it is harder to distinguish between facial configurations of emotions; the cue of motion aids in distinguishing between emotion facial expressions. While the effect of motion was found in the deaf group of children for real human faces, no advantage of dynamic versus static images was found for the hearing controls.

A limitation to these results is that near ceiling effects were exhibited for both groups of children in the identification of emotion in human faces. The focus on the three most basic emotions does not encompass all emotions that children begin to conceptualise during childhood. Matsumoto and Ekman (2004) highlight that the inclusion of at least the six basic emotions demonstrates improved ecological validity. Study 2 aimed to extend this finding to test deaf children's emotion recognition of all six of the basic emotions – happiness, sadness, anger, fear, disgust and surprise – in static and dynamic displays. As expected, hearing control children did not exhibit an advantage for dynamic images in line with previous research (Nelson & Russell, 2011). It has been reasoned that when clear prototypical facial expressions in natural stimuli are used, no advantage is gained by the use of motion. In contrast, the deaf children were shown to be significantly worse than the hearing children at accurately recognising static but not dynamic images displaying emotion in real human faces. Importantly, the deaf children's overall performance in emotion recognition paralleled that of hearing control children when using dynamic and real human faces.

Yet the majority of the emotions (except the more difficult expressions of fear and disgust) resulted in near ceiling effects as per the human faces in Study 1, meaning the possibility remains that the task was not sensitive enough to tap differences between deaf and hearing children. While emotion recognition is a natural, unconsciously occurring ability and it is encouraging that the deaf children performed well in comparison to controls, in reality emotion expressions in everyday life are more subtle and fleeting than the expressions portrayed by the exaggerated displays typically used in emotion recognition research (Montange et al., 2007; Russell, 1994).

Study 3 aimed to take account of the fact that in everyday life emotion expressions are subtle by testing deaf and hearing children's emotion recognition at varying degrees of intensity. It was suggested that because deaf children of hearing parents exhibit difficulties in ToM and perspective taking (e.g. Peterson & Siegal, 1995), it is possible that problems may be faced in interpreting subtle, fleeting emotion expressions that are typical of day-to-day experience. Further evidence suggesting that deaf children may not be so attuned to subtle expressions of emotion is that young deaf individuals are more likely to be exposed to exaggerated expressions through communication with parents (Koester et al., 2000) and exposure to sign language communication (Goldstein et al., 2000).

As per Study 2, the deaf children's overall performance paralleled the hearing control group children. The processing demands of this study were higher than in previous studies investigating emotion recognition in deaf children with a reduced display time of only 500ms, whereas the majority of previous studies gave no time limit (Hosie et al., 1998; Ludlow et al., 2010; Ziv et al., 2013). Subtle expressions were more difficult for deaf children to recognise, but no more difficult than the hearing children. These results are consistent with several other studies suggesting that emotion recognition in deaf children is comparable to hearing children's when assessment involves the use of static pictures (Hopyan-Misakyan et al., 2009; Hosie et al., 1998; Ziv et al., 2013) or video clips (Most & Aviner, 2009) of real human faces. These three studies highlight the importance of socially relevant information necessary for deaf children to make emotion judgements of facially expressed emotions, suggesting a particular reliance on salient visual cues in the absence of auditory information.

Deaf children's emotion production

This is the first study to investigate emotion production abilities in deaf children: a highly important skill given the social role expressions play in being able to send a signal of intent or emotional state to another individual (Harrigan et al., 2008; Lewis et al., 1987). The ability of deaf children to voluntarily encode the six basic facial expressions of emotion was examined using three elicitation methods: verbal labels, emotion signed stories and mimicry of dynamic clips of real people portraying prototypical facial expressions. The overall findings of Studiess 4a-c suggest a similar conceptual development of emotion in line with the emotion recognition results, implying the importance of socialisation of emotion and a role for language in emotion understanding.

The result indicating that overall deaf children's imitation of facial expressions of emotion parallels that of hearing children is encouraging given the socially facilitative role of this function (Fischer & Manstead, 2008). The importance of being able to overtly mimic another person's emotion state is to send a signal to indicate that the other person has been understood (Pfieifer et al., 2008). Deaf children's performance in the encoding of the six basic emotions elicited via a verbal prompt (i.e. *"show me… happy."*) revealed *better* performance in the accurate expression of sadness, anger, fear and surprise according to the judgement of human raters. Likewise, better overall performance of the deaf children was found for emotion signed stories. Here, clearly the argument that experience with non-verbal communication results in better emotion encoding is upheld (Goldstein et al., 2000). Despite research suggesting that some deaf children (of hearing parents) experience qualitatively poorer experience of early inter-subjectivity (e.g. joint attention: Prezbindowski et al., 1998), the current findings suggest that experience of sign language and the greater requirement for deaf children to express themselves through non-verbal means results in effective encoding of emotion expressions that are readily recognised by others.

The finding that both deaf and hearing children were able to produce expressions of happiness that received highest recognition by the human raters and the Face Reader™ software is unsurprising given the role of happiness in facilitating positive social relations (Field & Walden, 1982; Lewis et al., 1989; Volker et al., 2000). The more difficult emotions of anger, fear and disgust received consistently low Face Reader™ ratings, particularly in the label and story prompt conditions, suggesting that the children were less able to voluntarily produce the prototypical facial configurations. This is in line with Ekman's (1985) account explaining that the negative emotions are harder to voluntarily produce. In addition these findings highlight a methodological strength of the emotion production studies presented in this thesis – the inclusion of the ecologically and socially valid human judgement rating in addition to the more objective measure provided by the Face Reader™ software. While children may be developmentally limited in their ability to produce the prototypical facial expressions of emotion, the advantage of video clips is that human raters are able to benefit from additional dynamic emotion cues, such as cowering backwards with fear and the tongue protrusion for disgust (Gelder et al., 2004).

In all three conditions, deaf children's emotion encodings were rated as being consistently more intense than the hearing children's. As each culture is thought to adopt a different set of display rules that dictate the level of intensity of expression and when to mask and inhibit emotions (Ekman, 1972), it may be that experience with non-verbal emotions and sign language results in an emphasis on clear, intense emotion expression in deaf individuals (Goldstein et al., 2000). Of particular interest is that deaf children express the negative emotion of anger with greater intensity – an emotion that does not have a socially facilitative function (Hess et al., 2000). It could be that these emotions are clearly and intensely expressed facially by the deaf children due to a need to convey linguistic meaning non-verbally, compared with hearing children who may express their anger through language or tone of voice. Hearing children in western cultures are often encouraged to subdue expressions of anger as it is socially unacceptable to display angry outbursts (Lewis et al., 1987). On the other hand, deaf children are less likely to conceal anger to protect the feelings of others (Hosie et al., 2000) and demonstrate difficulties in emotion regulation (Wiefferink et al., 2012), which may explain the greater ratings of intense expressions of anger in Studies 4a-c. Further studies in naturalistic situations would be needed to confirm these suggestions in order to directly observe whether or not deaf children express or conceal anger to gain an accurate picture of the pattern of display rules in a real social context.

A parallel developmental pathway in emotion processing

Deaf and hearing children's comparable error patterns in Study 3, indicating a greater difficulty in recognising subtle than intense, exaggerated expressions of emotion, suggests a typical processing style in deaf children. These results are in accordance with the emotion recognition literature investigating the effect of intensity on typically developing children (Gao & Maurer, 2010; Herba et al., 2006; Montirosso et al., 2010). As expected, the hearing children's performance improved with age at recognising the comparably difficult subtle expressions. It has been reasoned that with age, either children become better at making subtle distinctions between expressions of low intensity suggesting a superior configural processing strategy (Maurer et al., 2002; Rump et al., 2009), or children become more effective at employing the more demanding featural strategy required to distinguish features in subtle expressions (De Sonnerville et al., 2002). Ludlow et al. (2010) similarly found that deaf children's processing style matched that of hearing control children in showing decreased performance on inverted faces, signalling a configural processing style. While Study 1 and previous studies suggest that deaf children find identifying emotion expressions more difficult in cartoons and synthetic stimuli than hearing children (Dyck et al., 2004; Ludlow et al., 2010; Wiefferink et al., 2013), the evidence suggests this does not appear to relate to any perceptual differences in emotion processing.

Further evidence that deaf children follow a similar developmental pathway to hearing children in emotion recognition lies in the pattern of misattributed 'errors'. Widen and Russell (2003) argue that the 'errors' in labelling inform how children understand emotions. Over the course of childhood it has been posited that an increasingly refined process of categorisation takes place, encompassing a broader range of discrete emotion terms (Widen & Russell, 2008a). In Studies 2 and 3, the deaf and hearing children showed a similar pattern in accuracy for each emotion, most accurately identifying happiness, followed by sadness, anger and surprise. Both the deaf and hearing children made most errors in labelling the more complex emotions of disgust and fear. The analysis of the emotion label misattributions in Study 2 showed that ‘errors’ were similar in valence and arousal (e.g. disgust was mistaken for anger) to the target emotion for both deaf and hearing children, consistent with Widen and Russell’s (2003) differentiation model. These results further support Hosie et al.’s (1998) initial finding that the ‘error’ profile in deaf and hearing children is comparable when labelling static pictures of real human faces.

Similarly, deaf and hearing children’s parallel pattern of errors in labelling (and therefore encoding) the emotion signed stories in Study 4b are consistent with Widen and Russell’s (2003) differentiation theory, given that anger was most commonly mistaken as sadness and happiness as surprise: in both instances, the stories were mistakenly labelled as an earlier occurring emotion category of the same valence. An additional complexity of identifying surprise in a story is that an understanding that the expectations of another were not met is required (Golan, Baron-Cohen, Hill & Golan, 2006). Yet deaf and hearing children did not differ in this ability. Interestingly, the deaf children’s performance on the signed stories was better than in previous studies (Gray et al., 2007; Ziv et al., 2013). This may reflect the use of SSE in the creation of the experimental stimuli, which better represents the everyday communication of these deaf children of hearing parents and provides additional cues such as facial expressions. Further studies inclusive of a greater number of children are needed to confirm this postulation.

A delay in deaf children’s understanding of disgust

It is interesting that deaf children’s performance in labelling and encoding disgust (elicited via a verbal label and imitation of a dynamic emotion video clip) was consistently poorer than the hearing children's performance; the finding is coherent given that disgust is the last emotion category to emerge in typically developing children (Widen & Russell, 2008c, 2013). In Study 2, the difference between deaf and hearing children was significant and the difference was marginally significant in Study 3. Further within group comparisons found that deaf children with HAs performed significantly worse than children with CIs and hearing control group children in labelling disgust in both Studies 2 and 3.

Widen and Russell (2008c) describe that the label, 'disgust', is easier for children to identify than the prototypical facial expression, contrary to the other basic emotion expressions (Widen & Russell, 2004). The disgust facial expression remains assimilated to anger until late childhood/adolescence. A reliance on only visual cues in absence of auditory cues may lead to a greater confusion with the emotion, anger, for deaf children. Given that emotion recognition is paired with emotion production (Goldman & Sripada, 2000; Boyatzis & Satyaprasad, 1994), it is reasonable to expect a difficulty in producing the expression based on a verbal label and mimicry of a dynamic emotion expression as found in Studies 4a and 4c. As emotion recognition has been proposed to occur through the process of mimicry via emotion contagion (Atkinson & Adolph, 2002), a lack of understanding of the emotion expression being viewed results in difficulty in imitating or correctly categorising the emotion.

Further support for Widen and Russell's (2010) theory of the acquisition of the concept of disgust is that all children in Study 4b (deaf and hearing) were able to correctly label the emotion signed stories that aimed to elicit disgust. In addition, there were no differences in deaf and hearing children's production of disgust when elicited via the emotion signed stories. While it may seem that inferring an emotion in a story is more advanced, research with typically developing children suggests that for more complex emotions (disgust, fear, social emotions e.g. embarrassment), there is an *inferiority* effect of face in comparison to a story. Indeed, both the deaf and hearing children were also all able to correctly provide a verbal label for the signed emotion stories eliciting fear in Study 4b, whereas the highest error rates were made for labelling fear in Studies 2 and 3.

The replication of the face inferiority effect (for disgust and also fear) in deaf children makes an important contribution to the debate on emotion development. It is not a trivial finding that deaf children are able to perform better in a verbal than a non-verbal task. This finding is inconsistent with the emotion signaling theory which argues that specific emotions should be easy to recognise via specific facial signals (Izard, 1971, 2007). Rather the results are consistent with Widen and Russell's (2010) notion that emotion understanding is rooted in a narrative structure known as 'scripts' operationalised as stories. The advantage stories pose is the contextualisation of an emotion within a narrative structure that is not provided by a facial expression alone. The finding that deaf children have a difficulty relative to the hearing control children suggests that they may have a delay in acquiring the 'script' for disgust. The ability to recognise disgust from the 'nose scrunch' prototypical expression alone requires a more sophisticated concept of disgust.

Deaf children's delay in social-cognitive ToM

The final study aimed to test deaf children's social-cognitive ToM as measured by the first and second order false belief task. A battery of tasks was devised and recorded in BSL, SSE and English by a CODA (a hearing native signer) to provide for all communication preferences and to avoid problems posed by a divide in attention between an experimenter and interpreter as had previously been faced (e.g. Peterson & Siegal, 1995). The deaf children's (of hearing parents) performance was no different to the group of preschool-aged children for all false belief tasks. Although there were no differences between the deaf and CA matched hearing children performance on the unexpected location task, the deaf children of hearing parents' performance was significantly worse on the unexpected content and second order false belief tasks.

The results are more encouraging than some earlier studies testing late signing and oral deaf children's ability on the false belief task, indicating a delay rather than a deficit, akin to Schick et al.'s (2007) study. The assistance of a CODA to administer false belief tasks in Study 5 and Schick et al.'s study emphasises the beneficial impact of reducing divided visual attention on task performance. The vast majority of deaf children also chose to view the task in SSE, which echoes the increasing popularity of this mode of communication.

Lip-reading ability and BSL receptive language scores of deaf children and BPVS scores of hearing children were found to predict performance for the unexpected content task, but only lip-reading was found to predict deaf children's unexpected location scores in Study 5. While this suggests that verbal ability is to some extent important, other language skills have also been shown to improve performance in false belief understanding that were not accounted for in this thesis, including sentential complements (de Villiers and de Villiers, 2000) and the ability to construct a narrative (Tomasuolo et al., 2012). Others argue that it is not specific language abilities, rather a reduced opportunity to discuss mental states, supported by evidence suggesting hearing mothers use fewer mental states when talking to their deaf infants than mothers of hearing infants (Morgan et al., 2014).

None of the deaf children of hearing parents were able to pass the second order false belief task, meaning that it is possible that the verbal demands of this task made it too challenging. Yet non-verbal first-order false belief tasks found no better performance of late signing and oral deaf children then verbal tasks (e.g. Woolfe et al., 2003), suggesting that the difficulty lies in a conceptual understanding more likely to be related to less experience in discussing mental states and specific language abilities (Schick et al., 2007). Future research could consider the use of a non-verbal second order false belief task as tested in typically developed hearing children (Hollebrandse et al., 2012), including older deaf children and children of different communication experiences (e.g. native deaf signers) to determine the age and language factors that contribute to mastering the task.

Linking social-perceptual and social-cognitive ToM

In the introduction to this thesis the importance of the study of deaf children's social cognition to extend beyond the false belief task to encompass a broader range of mind-reading abilities was highlighted, including the less considered ability of emotion processing (Hughes & Leekham, 2008). The findings suggest possible slight delays in emotion processing in addition to false belief understanding that may both be accountable to differences in socialisation for deaf children of hearing parents.

It has been suggested by several researchers that the early social-perceptual skills, including emotion recognition and imitation, are precursors and form the building blocks for the later emergence of a social-cognitive ToM (Baron-Cohen et al., 1993; Hobson, 1991, 1993). Children with ASD have been shown to display difficulties in the processing of more subtle displays of emotion (e.g. Law Smith et al., 2010; Volker et al., 2009) and in the belief based emotion of surprise (Baron-Cohen et al., 1993). The studies in this thesis have shown, however, that deaf children have shown no difficulty in comparison with hearing children in recognising surprise in faces or emotion stories, or in the overall ability to process subtle expressions of emotions. Likewise, no overall difficulty was found in the ability to imitate emotion facial expressions. Indeed, deaf children were shown to be *more* effective at encoding emotion expressions that were also greater in intensity. The outcome that deaf children faced problems with the false belief task instead supports Tager-Flusberg and Sullivan's (2000) proposal that social-cognitive ToM is dissociable from the 'online' attributions of emotions through the perception facial expressions and imitation (social-perceptual ToM).

Rather than any indication of an impairment of the neurocognitive structure, the within group variance in both deaf children's delays in the false belief task and the emotion processing of disgust is suggestive of difference in language exposure. Much less focus has been given to the notion that language ability, or conversational experience, may affect the development of emotion concepts. Widen and Russell's (2004, 2008a, 2008b, 2010) suggestion that learning the label is a crucial step in the acquisition of an emotion concept and the face inferiority (story superiority) effect highly implicates language in emotion concept acquisition (Feldman-Barrett, 2009). Deaf children's poorer performance in the emotion face recognition of disgust (and assimilation to anger) is supportive of this suggestion given that in general these children display delays in language development and have fewer opportunities to discuss emotions and formulate these concepts.

Feldman-Barrett et al. (2007; Feldman-Barrett, 2009) emphasise the importance a readily available emotion vocabulary has in being able to quickly identify and categorise emotion expression. Emotion vocabulary scores negatively correlated with overall scores in emotion recognition in Study 2. Verbal ability also predicted hearing children's intense emotion recognition scores in Study 3 - a relationship that has also been shown in a number of previous studies (Beck et al., 2012; Ruffman et al., 2003). Given that emotion recognition and language acquisition are both dependent on learning and categorising through experience it is a logical finding that the two may be interconnected. Therefore, having a good general or emotion vocabulary would suggest that emotion concepts are better formed and more accessible for the process of categorisation involved in emotion recognition.

No link between deaf children's language (BSL receptive scores) and emotion recognition scores on Studies 1-3 may reflect the limitation of this measure, particularly as the deaf children used SSE rather than BSL. Further efforts need to be made in devising appropriate methods to measure deaf children of hearing parent's language abilities to thoroughly explore the links between emotion recognition and language (Prezbindowski & Lederberg, 2003).

The finding that deaf children with CIs performed better than HA wearers, potentially suggests that these children may gain better access to language and the everyday social and linguistic aspects of emotions, allowing them to develop the appropriate social and cognitive abilities to facilitate emotion recognition (Peterson & Siegal, 1995). Certainly, the deaf children with CI implants in this study may be an exceptional group as there is great heterogeneity within the deaf population and CIs work with varying degrees of success (Bat-Chava & Deignan, 2001). There is a need for larger studies to further examine the difference between deaf children with HAs and CIs considering other factors such as age of implantation, level of hearing and language ability. Nevertheless these results suggest that some deaf children may gain better access to communication resulting in better opportunities for the socialisation of emotion.

Deaf children of hearing parents' delay in false belief understanding provides strong evidence for a conversational account of ToM acquisition and the role of language in the concept acquisition (Schick et al., 2007). The simulation account of ToM is one theory that considers the importance of the social environment that leads to opportunities for interaction (Harris, 1991). Similarly, Widen and Russell (2008a) propose that emotion processing may be conceptualised in the same way: in trying to understand the emotion of others, shown by effectively categorising, imitating or encoding a facial expression, children do not rely on an innate module but rather simulate the experience instead. Deaf children's mental state and emotion concept understanding develops in the same way as hearing children, but a reduced opportunity to overhear conversations about mental states results in some delays in acquisition.

Main strengths, limitations and future directions

The strength of the emotion recognition studies presented in this thesis are the consideration of ecologically valid and socially relevant measurement through the inclusion of real, dynamic facial expressions of varying degrees of intensity, and the more realistic reduced display time that better reflects emotion perception in everyday life. This study carefully ensured that the deaf children were matched to the hearing controls on measures of non-verbal and verbal ability, as well as CA, where previously it was uncertain whether emotion recognition findings related to aspects of cognition unrelated to deafness (Dyck et al., 2004; Ludlow et al., 2010).

Although ceiling results were found in Studies 1 and 2 in the recognition of real human faces, an attempt to overcome this was made by including some of the later developing emotions (fear, surprise and anger) and by increasing the task demands by reducing the display time and displaying emotions of lesser intensity. As the latest emotion to emerge in hearing children, disgust, posed most difficulty for hearing children, and Dyck et al. (2004) found delays in deaf children's emotion recognition with the inclusion of the more difficult emotion of contempt, future research could consider the development of the more complex emotions into adolescence. Emotion recognition of the social or self-conscious emotions, such as embarrassment and shame, could be explored in both facial expressions and emotion signed stories (Widen & Russell, 2010). Given that both ToM and self-conscious emotions involve an appreciation of social norms and the awareness of others, deaf children of hearing parents could face delays in developing this skill (Heerey et al., 2003).

This study was novel as it was the first to thoroughly investigate deaf children of hearing parents' voluntary emotion production abilities using three methods of elicitation (verbal prompt, emotion signed stories and imitation), with the use of two decoding methods to provide both objective (Face Reader™) and socially valid (human decoding) judgements. The generalisability of these findings is currently limited, however, due to small participant numbers. Future studies could consider the emotion production of spontaneous facial expressions of both deaf and hearing children in more naturalistic contexts. Particularly given that deaf children have been shown to have difficulties in emotion regulation (Wiefferink et al., 2012), studies conducted in a social context may be fruitful in further determining the regulation of negative emotions.

Social implications of findings

The theoretical and practical findings of this thesis can inform professionals and parents of crucial factors in the development of social and emotion cognition in a deaf child with hearing parents. The results of this study support the argument that language is important in the conceptualisation of emotion. Delays in social cognition and more complex emotions (i.e. disgust) in some deaf children indicates a need for educational planning to incorporate the promotion of emotion vocabulary development and foster mental state understanding through the provision of a linguistically rich environment. Parallel performance with hearing children in emotion processing and high levels of expressiveness suggests that improving deaf children's understanding of emotion and mental states in context and real-life social settings may be more beneficial than a focus on the visual perception of emotions. In addition, improved performance in emotion recognition through the use of socially relevant dynamic video clips highlights the importance of using ecologically valid materials with deaf children so to maximise understanding and facilitate communication.

Deaf children's choice to view the false belief task in SSE implies the usefulness of this communication method, suggesting the importance of exposure to sign and the employment of deaf/proficient signing professionals. Studies have suggested that mothers of deaf infants use fewer mental state terms in conversation with their infants in comparison with mothers of hearing infants (Morgan et al., 2014) and yet this type of discussion needs to be encouraged with parents at home as well as at school. Access to rich mental-state vocabulary with opportunities to express desires, and emotions and thoughts, as well as opportunities to respond to those of others, should be provided (Ziv et al., 2013).

The clear heterogeneity of deaf children born to hearing parents and great variation in individual performance suggests that a differentiated approach should be taken to cater for individual needs. Therefore, careful assessment of this group of deaf children is necessary to determine their social development. The finding that CI wearers did not perform better than deaf children with HAs on the false belief task indicates that language alone is not sufficient to develop social-cognitive understanding: while many oral deaf children may have good speech and vocabulary scores within the average range, these competencies may mask difficulties faced in groups and contexts involving multiple people (Punch & Hyde, 2011). The promotion of skills in social cognition, therefore, is paramount alongside linguistic support. Awareness of these difficulties particularly needs to be highlighted to professionals working with deaf children in mainstream schools without the additional support of a hearing impaired unit. Focusing on developing both linguistic and social abilities will positively benefit deaf children's well-being and successful integration into wider society.

Conclusion

To conclude, deaf children of hearing parents do not show any overall deficit in emotion processing. Rather, the emotion production studies encouragingly suggest that deaf children are able to voluntarily encode clearer and more intense expressions of emotion indicating a greater level of expressiveness. A similar pattern of development to hearing children is evidenced by the pattern of errors made in attributing an emotion label to faces and stories, and in finding subtle emotions more difficult to identify than intense facial expressions of emotion.

Difficulties in processing the emotion, disgust, for some children and problems with passing the false belief task strongly implicate language and a reduced opportunity to overhear conversations resulting in delays in the formulation of both of these concepts. The consistency across the emotion processing studies highlighting a specific difficulty with disgust is striking. Yet the inconsistency within the deaf group of children strongly implies that children can benefit from their own environmental experiences in developing mental states and emotion concepts, and it is vital that this is promoted for the benefit of their social development.

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APPENDICIES

APPENDIX A

Participant Information Sheet

Child Name:

1.Congenital or acquired deafness?

2. Level of deafness (severe/moderate/profound)

3. Age at which child diagnosed as deaf

4. Cause of deafness

5. Age at which child learnt to sign

6. Child's communication preference – oral/sign or both

7. Do they wear hearing implants/cochlea aids? If so, what age did they start wearing them?

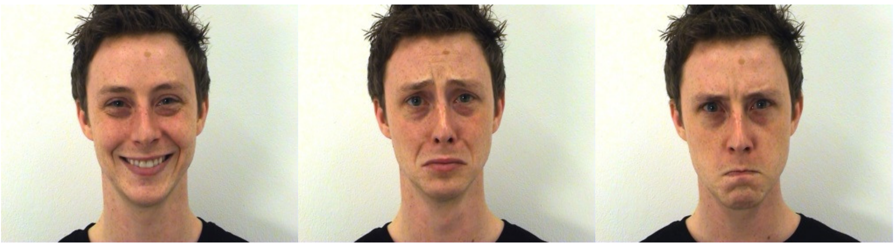
8. Number of members who sign in the family, who they are and level of signing (BSL level)

9. Any members of the family who are deaf? If so, who?

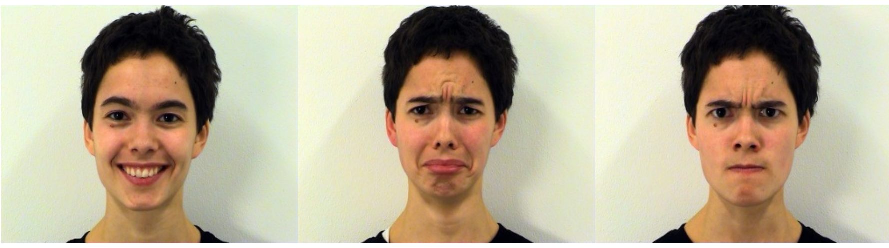
Appendix B: Human, human cartoon and non-human cartoon faces: happiness, sadness, anger

Human faces *(source: ADFES; Van de Schalk et al., 2011)*

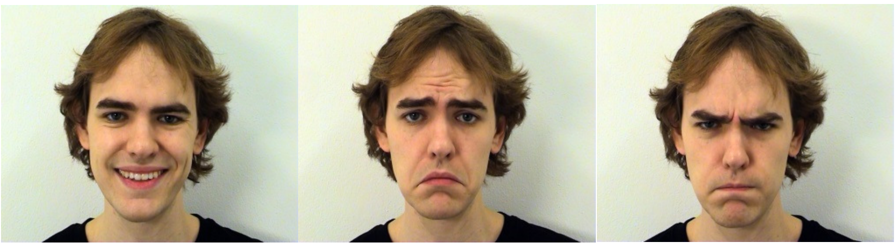
M12



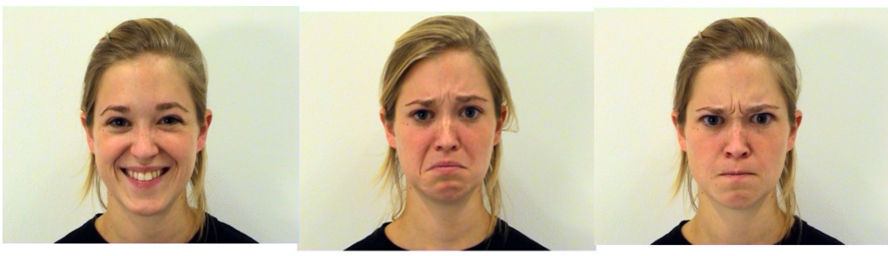
F4



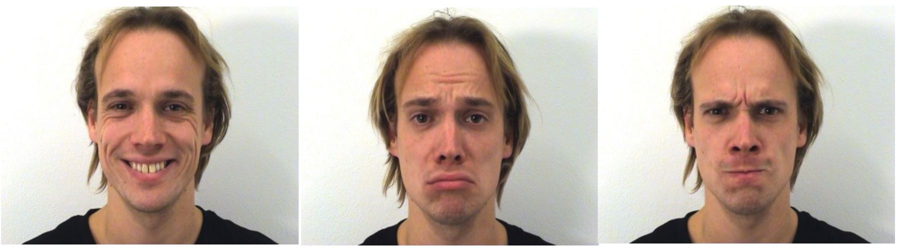
M8



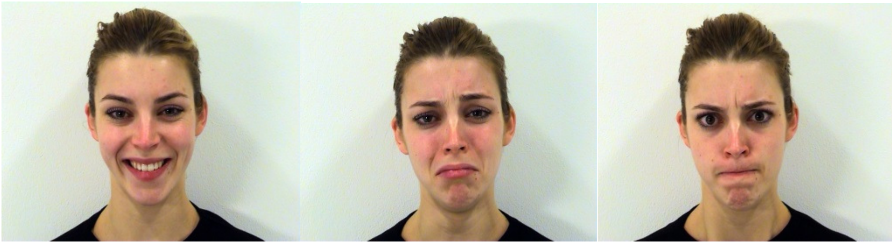
F3



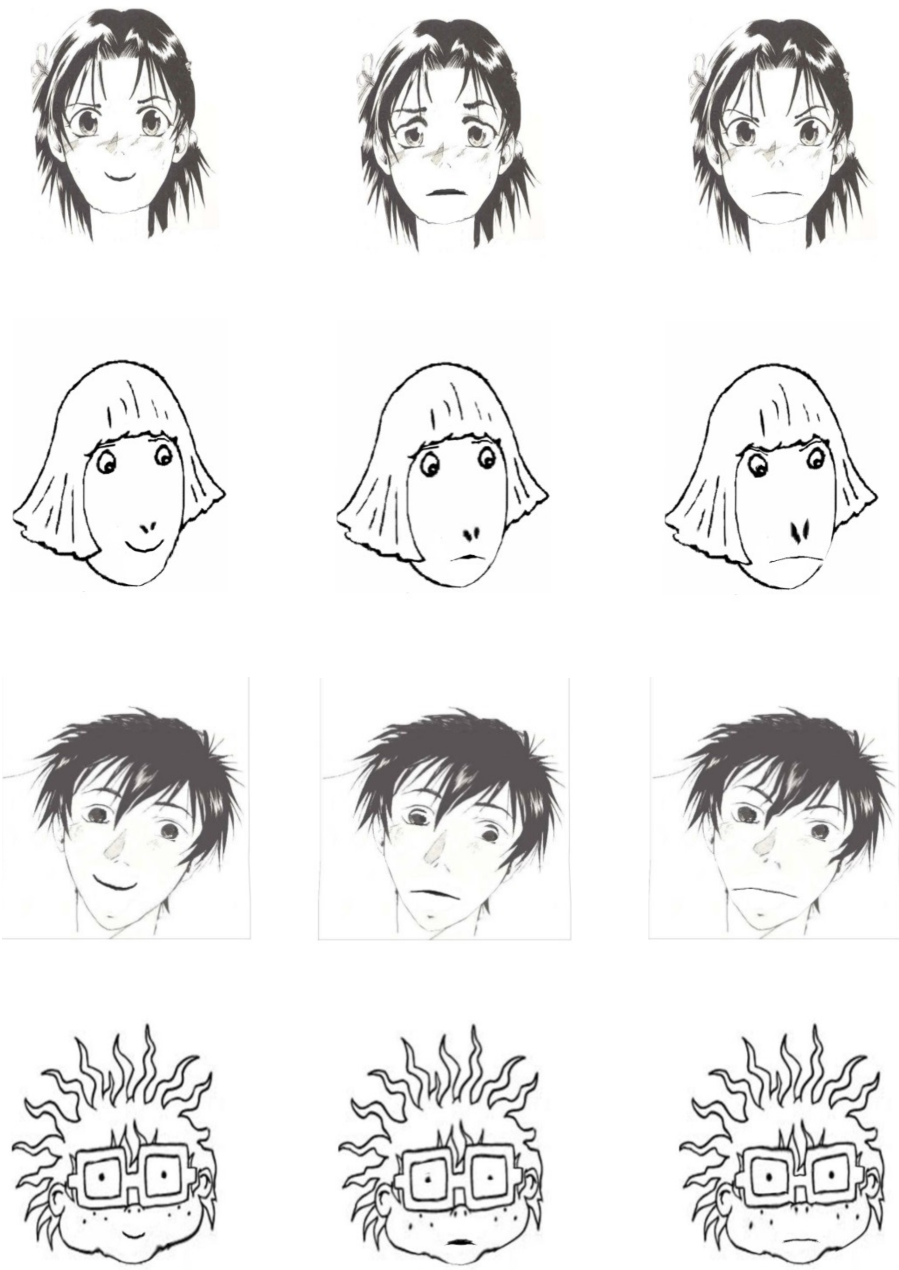
M11

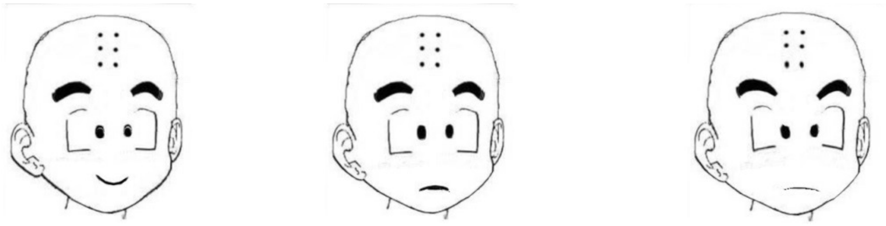


F1

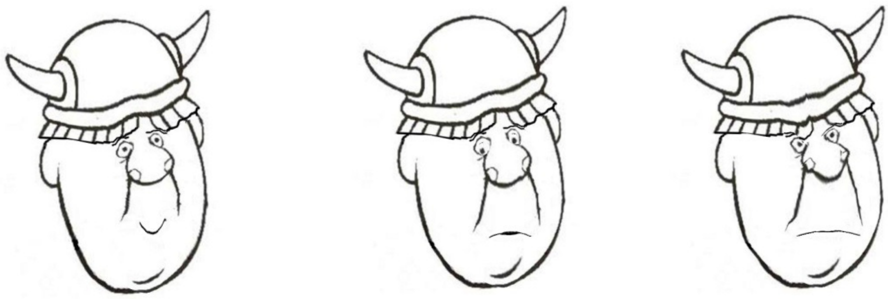


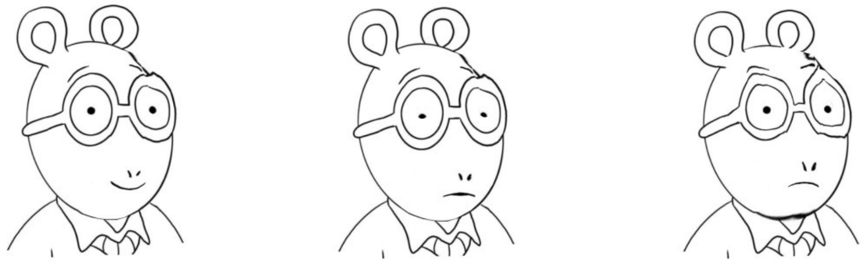
Human like cartoon faces

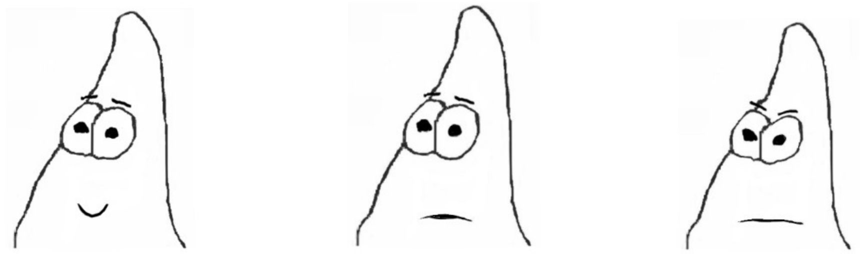


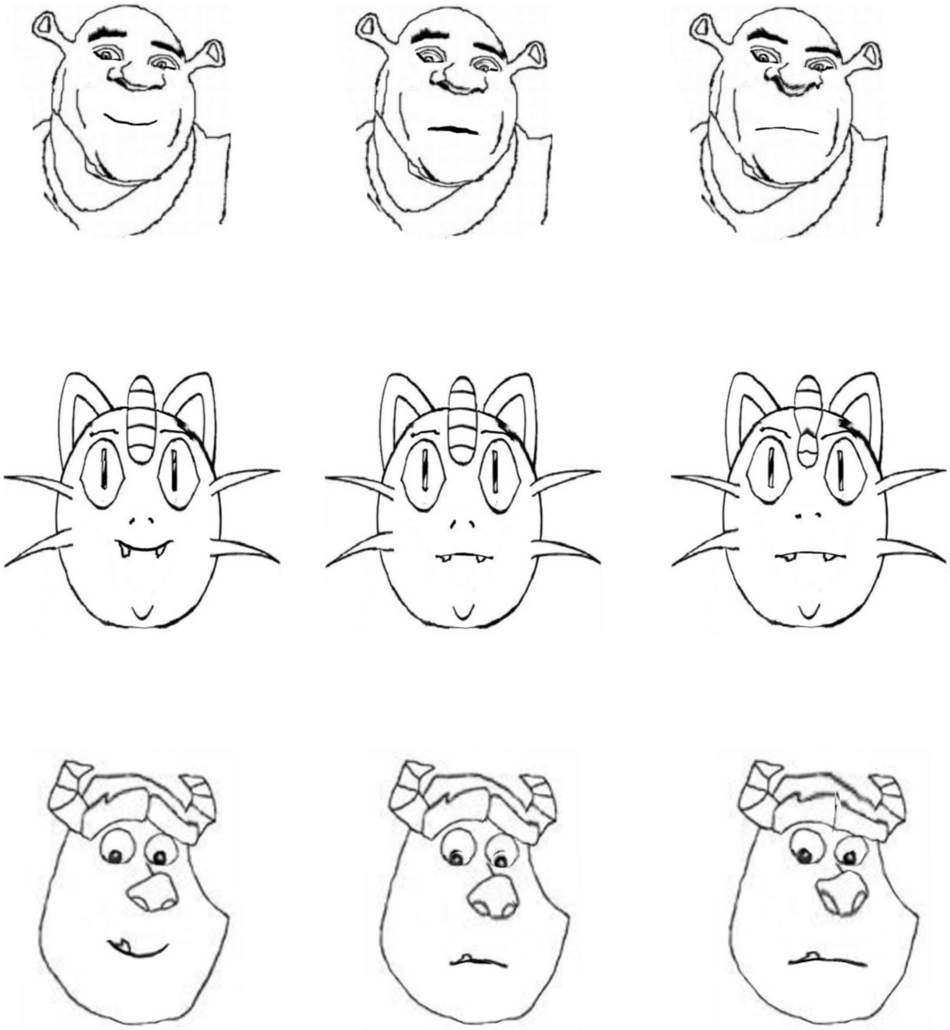


Non-human like cartoon faces



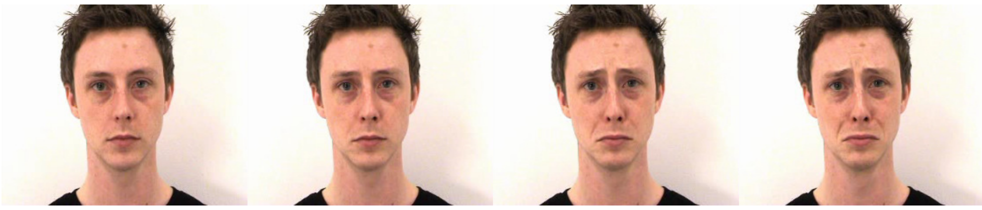






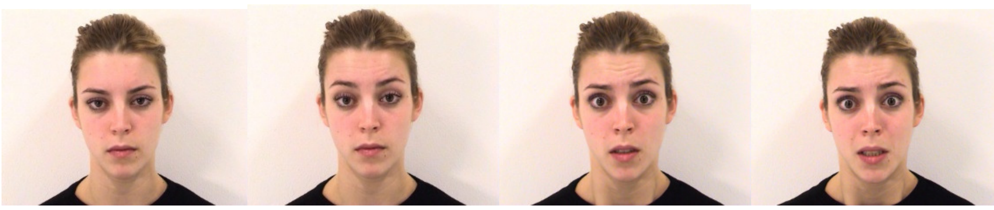
Appendix C: Examples of dynamic video clips of emotion facial expressions of increasing intensity (0-25%, 25-50%, 50-75%, 75-100%; adapted from ADFES, Van der Schalk et al., 2011)

M11 Happiness



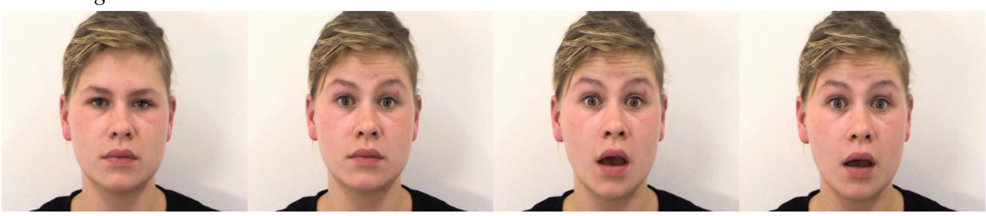
M12 Sadness

F5 Anger



F1 Fear

M11 Disgust



F5 Surprise

Appendix D: Pilot ratings of emotion stimuli: percentage correct and mean and standard deviations for intensity ratings (on a 5-point Likert scale from 1-not at all, to 5-extremely intense).

Emotion	***Level***	**Percentage correct**	**Intensity rating**	
			M	***SD***
Happiness	0-25%	55.17%	1.46	(.77)
	25-50%	98.85%	2.33	(1.02)
	50-75%	100%	4.13	(.76)
	75-100%	100%	4.45	(.73)
Sadness	0-25%	71.26%	1.64	(.9)
	25-50%	65.52%	2.15	(1.05)
	50-75%	88.51%	2.86	(.96)
	75-100%	94.25%	3.37	(1.0)
Anger	0-25%	6.9%	1.57	(.88)
	25-50%	55.17%	2.0	(.82)
	50-75%	79.31%	2.22	(.96)
	75-100%	83.9%	3.67	(.95)
Fear	0-25%	6.9%	1.66	(.91)
	25-50%	8.05%	2.26	(.96)
	50-75%	60.92%	3.69	(.78)
	75-100%	77.01%	3.84	(.87)
Disgust	0-25%	28.74%	1.45	(.79)
	25-50%	80.46%	2.21	(.79)
	50-75%	85.06%	3.26	(.81)
	75-100%	83.91%	4.18	(.84)
Surprise	0-25%	8.05%	1.55	(.86)
	25-50%	97.7%	2.43	(.94)
	50-75%	97.7%	3.98	(.86)
	75-100%	98.85%	4.08	(.7)

APPENDIX E. Emotion Signed Stories (SSE) and pilot study emotion labels and intensity ratings

Emotion	Story	Target emotion percentage correct	Accepted synonyms	Median intensity (1 = not intense; 7 = very intense)**
Happiness (1) *	It was Ben's birthday. All his friends came to his birthday party. They all ate birthday cake. Ben got lots of presents. Then Ben and his friends played some games. Ben gave his friend a big hug.	98.11%	*Joyful, cheerful, loved, fondness, delight, warmth, pleased, affection*	7 (1)
Happiness (2)	Ben was on holiday. The sky was blue and the sun was warm. Ben went to the beach with his dad and sister. They made sandcastles and swam in the sea. After, they had an ice-cream.	98.11%	*Content, relaxed, cheerful, joy, nicely pleasant, excited*	6 (1.5)
Sadness (1)*	Ben went to feed his pet goldfish. But it wasn't swimming. It wasn't even in the tank. Ben's fish had died. He really missed his fish.	92.23%	*Misery, mourning, grieved, depressed, upset, trauma, miserable*	5 (1.75)
Sadness (2)	Ann looked out of the window. Her dad's car drove off and disappeared around the corner. Ann couldn't see her dad for a month. She lay down on her bed.	96.23%	*Upset, hurt, unhappy, lonely, numb*	6 (2)
Anger (1)*	Ben was at nursery. He spent a long time building a block tower. So long that the tower was very tall. A boy came and touched his tower. Ben said, "Be	98.11%	*Frustrated, mad, furious, aggressive, annoyed, infuriated*	7 (2)

	careful." But the boy knocked it over anyway. Ben wanted to yell at that boy and hit him.			
Anger (2)	Ben looked in his bag. His pen had disappeared. He looked up and saw a boy running away with it. His fists began to tighten.	98.11%	*Frustrated, agitated, rage, annoyed, outrage*	5 (2)
Fear (1)*	Ben was in his bed. He was all alone and it was very dark. He heard something moving in the wardrobe. He didn't know what it was. He wanted to hide under the bed. Then he heard the wardrobe door open. Ben wanted to run away.	98.11%	*Scared, nervous, anxiety, terrified*	6 (1)
Fear (2)	Ann was walking home. It was very dark. She saw shadows moving. The wind was blowing hard. She started to run.	100%	*Scared, terrified, horror, worried, anxious, paranoid, panic*	5 (2)
Disgust (1)*	Ben found an apple. It looked big and juicy. Ben took a big bite. Then he saw that there was a worm in the apple. He spat it out as fast as he could and threw the apple on the floor. He did not want to touch it.	88.68%	*Repulsed, sick, dislike, revulsion*	6 (2)
Disgust (2)	It was dinner time. Ben's mum gave him a bowl of soup. It smelt lovely. Ben started to eat the soup. Then he noticed a hair floating in it. He pushed the bowl away.	92.45%	*Sick, horrified, dislike*	5 (1.75)

Surprise (1)	It was Ann's birthday. When she got home, she looked for her family. She couldn't find them anywhere. She walked into the sitting room. Suddenly, the lights turned on. All her family were there. They shouted, 'Happy Birthday!'	81.13%	*Shock*	6 (2)
Surprise (2)	Ben was in his bedroom. He saw an old cardboard box on his bed. He picked it up to move it. It was heavy. Suddenly, out jumped a rabbit. Ben dropped the box. It was a new pet rabbit.	56.6%	*Shock*	5 (1)

*Adapted from Widen and Russell (2002); ** Inter-quartile range in bracket

Appendix F: Emotion Signed Story example: Ann's surprise birthday

 [It was][6] A-	 -nn's
 birth	 -day

[6] Section in brackets is only spoken and not signed

	
When [she got]	home
	
she	looked

	
[for her] family	[she] couldn’t find
	
any	-where

 Ann	 walked
 [into the] sitting	 room

 suddenly	 [the] lights turned on
 [all her] family	 [were] there

 [they] shouted	 ‘Happy
 Birth-	 -day!’

Appendix G: Individual results for children's labelling of emotions felt by characters in signed emotional stories

Participant	Group	Age	Happy 1	Happy 2	Sad 1	Sad 2	Angry 1	Angry 2	Fear 1	Fear 2	Disgust 1	Disgust 2	Surprise 1	Surprise 2
1	D	9y0m	H	H	S	S	A	St	F	Sc	DLi	DLi	Su	H
2	D	7y0m	E	H	S	S	A	A	Sc	Sc	D	D	E	E
3	D	11y2m	H	H	S	S	S	A	F	F	D	D	Su	Su & H
4	D	8y10m	H	E	S	S	S	A	F	F	D	D	Su & H	Su & H
5	D	6y7m	H	H	S	S	S	A	Sc	Af	D	D	H	H
6	H	8y11m	H	H	S	S	A	A	F	F	D	D	Su	Su
7	H	7y7m	H	H	S	S	S	St	F	F	D	D	H	H
8	H	10y1m	H	H	S	S	A	A	F	F	D	D	Su & H	Su
9	H	6y10m	H	H	S	S	A	S	F	F	D	D	H	H
10	H	7y6m	H	H	S	S	A	A	F	F	D	D	Su	F

Appendix H: False belief task story scripts

1. ***Sally-Anne (Girl-Boy) unexpected change in location false belief task: Marble Story***

Hello! My name is Anthony. I am going to tell you a story and then when we've finished I'm going to ask you some questions.

The story I'm going to tell you involves two dolls. Here is the girl [*pick up the girl sitting on the table*]. Here is the boy [*pick up the boy sitting on the table*].

So, which one is the girl? [*pause*] Which one is the boy? [*control/naming question*].

The girl has a basket [*hold up basket*]. The boy has a box [*hold up box*].

The girl has a marble [*show marble*]. And she puts the marble in to her basket and goes out to play [*act out and remove the girl from view of camera].*

Now, while the girl's away and cannot watch, the boy takes the marble out of the basket and puts it into his own box [*act out*].

So now, the girl comes back [*bring the girl back into the scene between the box and the basket*].

Where will the girl look for the marble? [*belief question*].

Where is the marble now? [*reality control question*].

Where did the girl put the marble in the beginning? [*memory control question*].

NB. Girl and Boy exchanged for Sally and Anne to eliminate need for finger spelling names, highlighted by Peterson and Siegel (1995) as placing extra demands on attention span and memory of children.

2. ***Unexpected change in location false belief task: Hidden Cakes***

[*Boy and Girl sit in toy kitchen. Girl sits by blue cupboard and Boy sits by green cupboard*]. The boy has made some cakes, six of them [*point to boy*]; and he puts them in the green cupboard to cool down [*act out*]. And while they are cooling, he goes off to play [*act out and remove boy from view of camera*].

While the boy's away, the girl goes to the green cupboard, takes the cakes, and puts them into the blue cupboard *[act out*].

Now the boy comes back [*bring boy back into the scene and sit by blue cupboard*].

Where will he look for his cakes? [*belief question*].

Where are the cakes now? [*reality control question*].

Where did the boy put the cakes in the beginning? [*memory control question*].

3. Unexpected content task: Hungry Boy (Cereal)

Here is a boy [*place boy on table in front of camera*]. He is very hungry.

Here is his favourite cereal - Crunchy Nut Clusters [*place the cereal on the table next to the doll*].

What do you think is inside the cereal box? [*Point to the box. Pause*].

Let's look and see what's inside the box [*open box, remove pencils, hold up in view of the camera and put back inside*].

What was inside the box/? [*pause*].

What did the boy think was inside the box before we looked inside? [*pause*].

What did you think was inside the box before we looked inside? *[pause*].

How would the boy feel when he found pencils inside the box? Would he be happy or would he be sad?

4. ***Unexpected content task: Hungry Boy (Smarties)***

Here is a boy [*place boy on table in front of camera*]. He is very hungry.

Here are his favourite sweets - Smarties [*place the Smarties tube on the table next to the doll*].

What do you think is inside the tube? [*Point to the tube. Pause*].

Let's look and see what's inside the tube [*open tube, remove red crayon, hold up in view of the camera and put back inside*].

So, what was inside the tube? [*pause*].

What did the boy think was inside the tube before we looked inside? [*pause*].

What did you think was inside the tube before we looked inside? *[pause*].

How would the boy feel when he looked inside the tube and found a crayon? Would he be happy or would he be sad?

5. Second order false belief task: The Ice-Cream Story

A boy and a girl are playing together in the park. They see the ice-cream man coming. The girl really wants to buy an ice-cream cone, but she doesn't have any money. She feels really sad. The ice-cream man says to the girl: "Don't be sad, you can go home and get some money. I'll be here all day long." So the girl goes home to get money for an ice-cream. The boy, he stays in the park to play.

"Why did the girl go home?" [*Probe Question 1*]

"What did the ice-cream man say to the girl?" [*Probe Question 2*]

The ice-cream van started to drive away. And the little boy said, "Hey, where are you going?" And the ice-cream man said, "I'm going to the school to sell ice-cream. I can sell more ice-cream there." Look, there goes the ice-cream man, driving away to the school.

"What did the ice-cream man tell the boy?" [*Probe Question 3*]

Now, the boy, he goes home to his house to get some lunch. Remember the girl – she's gone home to her house to get some money for ice-cream.

The little girl stepped outside of her house. As she did, the ice-cream man came by. The girl saw the ice-cream van and she said, "Hey, where are you going?" And the ice-cream man said, "I'm going to the school; I can sell more ice-cream there," says the ice-cream man. And the little girl said, "Oh good, because I've now I got some money for an ice-cream cone; I'll follow you to the school." And off they went.

Do you remember the little boy?

"Does the little boy know that the ice-cream man went to the school?" [*Probe Question 4*]

"Does the boy know that the ice-cream man told the girl he was going to the school?" [*Linguistic control question*].

"Does the girl know where the ice-cream man is?" [*Non-linguistic control question*].

"Does the girl know that the boy knows where the ice-cream van is?" [*Second-order ignorance question*].

Now, the boy's finished his lunch and so he goes over to the girl's house to play with her. When he gets there, he knocks on the door. The girl's mother comes to the door, and the little boy asks her where the girl is. So the mother says, "She's gone off to buy an ice-cream cone."

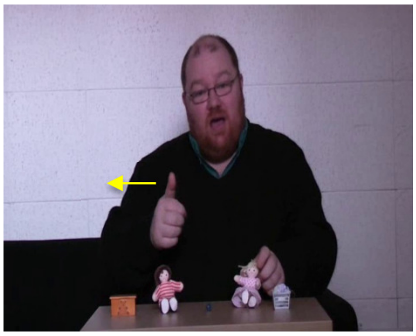
The little boy then goes off to try and find the girl.

Now, remember, the little boy does not know that the ice-cream man told the girl where he was going. [*Memory aid*]

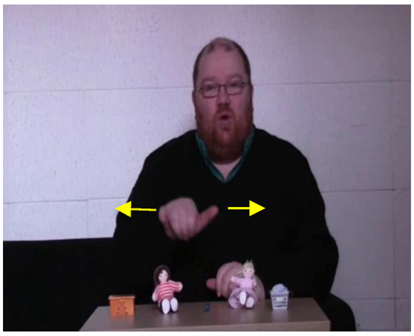
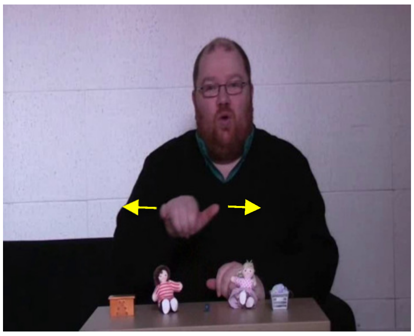
"Where does the boy think that the girl went to buy an ice-cream cone?" [*Second-order false-belief question*]

"Why?" [*Justification question*].

Appendix I: SSE Boy-Girl unexpected change in location false belief task

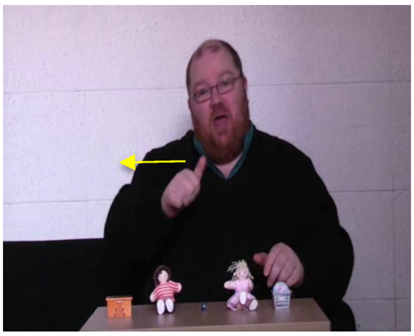
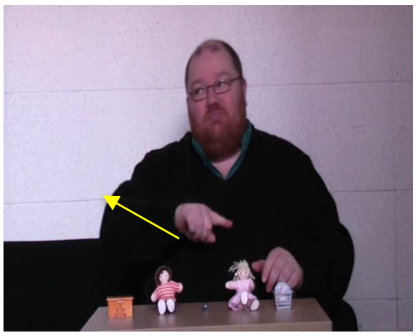
 This	 story
 involves	 two
 dolls	 [a][7] girl
	 and then

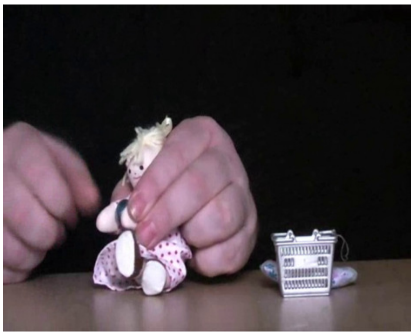
[7] Section in brackets is spoken and not signed

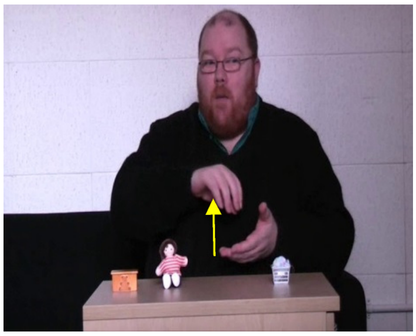
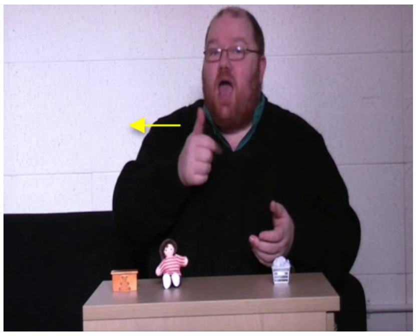
 [a] boy	
 Which	 one
 [is the] girl?	 <pause>
 Which	 one

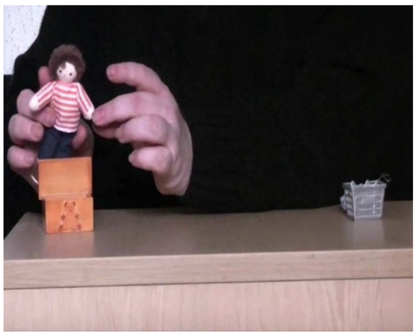
 [is the] boy?	 <pause>
 [The] girl	 has [a]
 basket	
	 [The] boy

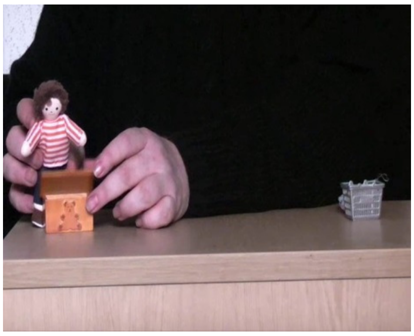
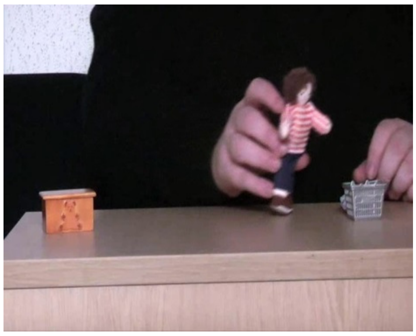
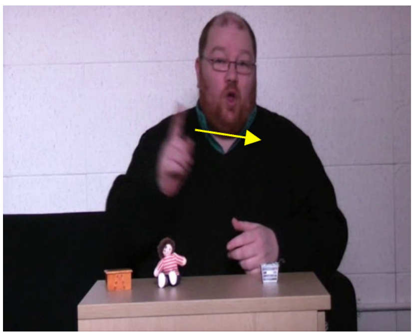
 has	 [a] box
	
 [The] girl	 has
 [a] marble	

 [the] girl	 puts
 [the] marble	 inside
 [her] basket	
 and then	 goes

 [to] play	
	
	 Now
 [the] girl's	 away

 [and] can’t	 see
 [the] boy	 picks up
 [the] marble	 and then
 puts [it]	 inside

 [his] own	 box
	
	
	

	
	
 Now	 [the] girl
 comes back	

 Where	 [will the] girl
 look	 [for the] marble?
 Where [is the]	 marble
 now?	 Where

 [did the] girl	 put
 [the] marble	 [in the] beginning?