

Emotion production of facial expressions: A comparison of deaf and hearing children

Abstract

The production of facial expressions is an important skill that allows children to share and adapt emotions during social interactions. While deaf children are reported to show delays in their social and emotion understanding, the way in which they produce facial expressions of emotions has been relatively unexplored. The present study investigated the production of facial expressions of emotions by young congenitally deaf children. Six facial expressions of emotions produced by 5 congenitally deaf children and 5 hearing children (control group) were filmed across three tasks: 1) voluntarily posed expression of emotion 2) responding to social stories 3) intentionally mimicking expressions of emotion. The recorded videos were analysed using a software based of the Facial Action Coding System (FACS), and then judged by adult raters using two different scales: according to the emotion elicited (i.e. accuracy) and the intensity of the emotion produced. Results using both measurement scales showed that all children (deaf and hearing) were able to produce socially recognisable prototypical configuration of facial expressions. However, the deaf children were rated by as adults as expressing their emotions with greater intensity compared to the hearing children. The results suggest deaf children may show more exaggerated facial expressions of emotion, possibly to avoid any ambiguity in communication.

Key words: Emotion production, deafness, facial expressions

1. Introduction

Deaf children of hearing parents have been considered to have a delay in the understanding of other peoples' emotions, an important component of the development of Theory of Mind (ToM; e.g. Peterson & Siegal, 1995, 1999). While the ability to produce facial expressions of emotion has been studied in other clinical populations with reported ToM difficulties, including children with Autism Spectrum Disorder (ASD; Volker, Lopata, Smith & Thomeer, 2009), and congenitally blind children (Galati, Sini, Schmidt & Tini, 2003; Roch-Levencq, 2006), this ability has received comparatively less attention in children who are deaf or hard of hearing.

Facial expressions provide a non-verbal means of expressing and communicating emotions. For example, the ability to read others' emotional expressions allows one to predict their actions based on these expressions (Begeer, Rieffe, Terwogt & Stockmann, 2006; Heerdink, van Kleef, Homan & Fischer, 2015). The production of facial expressions is also an important skill in allowing one to share and adapt behaviours during social interactions (Grossard et al., 2018). As such, being able to interpret and produce facial expressions of emotions contributes to successful social functioning (Ekman, 2005).

It has been suggested that there may be differences in the way deaf and hearing children are able to learn about emotions since many deaf children have limited access to a shared language, and consequently they have fewer opportunities for incidental learning and communication about their own and others' experiences of emotion (Morgan et al., 2014). For example, Morgan et al. (2014) showed that hearing parents of deaf children (who are not fluent in a sign language) used fewer mental state terms, including the labeling of emotions, than hearing parents of hearing children, which they argue is linked to delays in social cognitive development (Morgan et al., 2014). A large number of studies have found delays in emotion understanding in children who are deaf or hard of hearing born to hearing parents,

such as emotion attribution from situational cues (Gray, Hosie, Russell, Terwoft, & Smitt, 2003) and understanding the causes of emotions (Rieffe, Terwoft & Smit, 2003); yet research addressing the recognition of facial expression of emotion has mixed findings. For example, pre-schoolers who are moderately or profoundly deaf have been shown to have difficulty in emotion recognition (Most & Michaelis, 2014), as have deaf children using hearing amplifications (hearing aids (HAs) and Cochlear Implants (Cis; Wiefferink, Rieffe, Ketelaar, De Raeve, & Frijns, 2013). However, more similar performance between deaf and hearing children has been reported in those over 6 years of age (Most & Aviner, 2009; Hosie, Gray, Russell, Scott & Hunter, 1998; Ziv, Most & Cohen, 2012). In addition, similar ability on emotion recognition between deaf and hearing children has been found once language ability has been controlled for (Dyck, Farrugia, Shochet & Holmes-Brown, 2004; Jones, Gutierrez & Ludlow, 2018), suggesting that delays in emotion understanding may be directly related to problems in language development.

One typical consequence of being born deaf is that children are often reliant on sign language to communicate. For example, deaf children in the UK may learn British Sign Language (BSL), a fully developed, natural language with its own grammar; and/or Sign Supported English (SSE), a variant that combines signs and the word order of English language. In addition to grammatical information, an important feature of sign languages is that facial expressions also convey emotional content, so that a facial expression can alter the meaning of a word or sentence. Deaf people use facial actions that provide sign language prosody, which functions in sign language like intonation does in spoken languages (Dachovsky & Sandler, 2009). For example, the sign for the word “angry,” will change to “very angry” with a change in the facial expression’s level of intensity alone.

It is possible that deaf children’s own expressive behavior may be influenced by the use of certain linguistic facial expressions (e.g., yes/no questions are associated with raised

eyebrows) when they learn to communicate using a variation of sign language (Hosie et.al., 1998). On the one hand, it has been posited that the appropriation of some facial expressions for linguistic purposes may diminish their importance for the expressions of emotions (Most & Aviner, 2009). Most and Aviner (2009) suggest that deaf individuals may focus more on the mouth region to lip-read, consequently restricting the amount of emotional information captured from the eyes region of their communication partner. On the other hand, the appropriation of certain facial expressions as linguistic markers has been suggested to refine and enhance deaf children's expressive knowledge and control (Gray, Hosie, Russell, & Ormel, 2001). Indeed, several studies have found deaf signers to attend to faces more than hearing individuals (Mitchell, Letourneau, & Maslin, 2013; Megreya & Bindemann, 2017), and both deaf and hearing signers (adults and children) perform significantly better than non-signers in distinguishing among similar faces (e.g., the Benton Faces Test; Bettger, Emmorey, McCullough, & Bellugi, 1997). Moreover, studies involving adult hearing signers showed better accuracy in producing (Goldstein, Sexton & Feldman, 2000), as well as recognizing facial expressions of emotion than non-signing peers (Goldstein & Feldman, 1996).

Since facial actions have developed within sign languages to communicate language and emotion, it is plausible that exposure to sign language provides further advantages to deaf individual's face processing abilities (Denmark, Atkinson, Campbell & Swettenham, 2019). However, any advantages for face processing may not just be an effect of sign language proficiency, rather it has been suggested that deafness itself places a greater dependence on the visual channel for communication. Therefore, regardless of ability to sign, people who are deaf attend more closely to facial actions that serve communication purposes (Hauthal, Neumann & Schweinberger, 2012).

If facial expressions of others are important in navigating social interactions, it is also likely that one's own facial displays are also important (Paul, Shriberg, McSweeny, Cicchetti, Klin, & Volkmar, 2005). Studies addressing emotion production in typically developing children have highlighted that many variables can influence the production of emotions. For example, Grossard and colleagues recently explored factors that influence emotion production in children aged 6 to 11 years (Grossard et al., 2018). These authors found emotion production to improve with age, and to be better displayed when the children were asked to produce emotions on request compared to when they imitated the expression.

Research addressing the way in which deaf children develop and master their production of facial expression has remained relatively unexplored. However, a recent study carried out by Denmark and colleagues (2019), examined the production of facial expressions by deaf children and deaf children with comorbid ASD. These children were requested to produce BSL versions of a video story requiring them to use facial signals of both intent and emotion using the BSL Production Test (Herman, Rowley, Mason & Morgan, 2004). The deaf children without comorbid ASD were found to be as accurate at producing facial expressions as the adult native signer narrating the videos.

The main aim of the current study was to explore the ability of deaf children to produce facial expressions of emotion in comparison to hearing controls, using three different tasks. Given that ninety percent of deaf children come from families who are themselves hearing (Mitchell & Karchmer, 2004), the focus of the current study was to address emotion production in deaf children from hearing families.

The first task compared the ability of deaf and hearing children to voluntarily produce facial expressions of emotions in response to verbal labels. Being able to voluntarily pose facial expressions of emotion is important for social communication (Lewis, Sullivan & Vasen, 1987), as it allows emotional states and intentions to be communicated to another

person (Harrigan, Rosenthal & Scherer, 2008). The ability to voluntarily express emotions may allow children to better control their facial expressions, which is crucial in regulating and masking emotions (Calkin, 1994). Hosie and colleagues (2000) found deaf children to have more difficulties explaining their reasons for concealing their emotions, particularly in the context of feelings of others. It is therefore conceivable that difficulties with the regulation of their own facial expression may have an effect on their overall ability to control the production of facial expressions. Alternatively, as deaf individuals are reliant on the visual channel for communication, this may result in enhanced expressive knowledge and control (Denmark et al., 2019; Gray, Hosie, Russell, & Ormel, 2001).

An alternative to using verbal prompts to encourage the voluntarily production of facial expressions is to provide a contextual story detailing a stereotypical emotional event (Boyatzis & Satyaprasad, 1994; Profyt & Whissell, 1991). Therefore, the second task aimed to investigate deaf children's production of emotional expressions in a social context by signing prototypical stories aimed at eliciting specific emotions. Previous studies have shown that deaf children have been delayed in their understanding of emotional stories when responding verbally or by identifying the correct emotion facial expression (Gray et al., 2001, 2007; Rieffe, Terwogt & Smit, 2003), and to have problems in ToM (Peterson & Siegal, 1995, 1999). As a result, it was expected that deaf children might have more difficulty than hearing children in their ability to interpret the correct emotion from the story, and consequently be less accurate in displaying the appropriate facial expression of emotion.

The third task involved children to intentionally mimic 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). Being able to understand and identify how others feel is critical to successful social interactions. For example, Rogers and Pennington (1991)

proposed that the 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, it is conceivable that some difficulties in emotion mimicry may also be found in deaf children because of some evidence of difficulties in emotion recognition (e.g. Dyck et al., 2004; Ludlow et al., 2010) and joint attention (Loots, Devisé & Jacquet, 2005).

The assessment of facial expressions broadly falls into two categories: measurement studies and judgement studies (Volker et al., 2009; Wagner, 1997). Therefore, the children's ability to produce emotions from the three different tasks was assessed using two methods: one based on the Facial Action Coding System (FACS, Ekman et al., 2002), and the second one based on presenting facial expressions to a group of judges. The current study utilised Noldus FaceReader™ software (version 4) specialized in analyzing the emotions described by the FACS, detecting changes in the features of facial expressions. While FaceReader™ can provide an objective reading of the intensity of movement involved in changing facial expressions, it is unable to evaluate internal-state information of the emotion produced by these facial movements (Wagner, 1997). A judgement methodology was implemented alongside FaceReader™ to provide a socially valid measure to assess the encoded facial expressions of emotion (Rosenthal, 1982). 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 misinform aspects of emotion expression produced by the children (Lewis et al., 1987).

2. Method

2.1 Ethics

Ethics was granted by the Anglia Ruskin University Research Ethics Subcommittee.

Informed, written consent was first obtained from the parents for their children to be able to participate. Parents of each of the children included in the videos provided written consent not only for their child to be filmed doing the tasks, but also for the films to be watched by adult raters. Once parents had provided permission for their child to take part in the study, consent was then sought from the children. Each task was explained to the children in the appropriate language (i.e. Sign Supported English for the deaf children). Written and verbal consent was obtained from all children included in the study. Written consent was also sought for the adult raters taking part in the rating of the videos.

2.2 Participants

2.2.1 Deaf and hearing children

Children were recruited from three mainstream primary schools, with a special unit for hearing impaired children, across the East and South East of England. Deaf children were recruited if they had the presence of congenital/pre-lingual hearing loss at a moderate (>50 db)-to-severe (>60 db) or profound level (>90 db) in their better ear and no known concomitant disorders such as autism, attention deficit disorder or cerebral palsy. Permission was gained from five parents of deaf children to take part in the study, and so five hearing controls children were selected from local mainstream primary and individually matched to the deaf sample based on age, sex and ethnicity (all participants were white British). All hearing children were required to have no history of hearing loss and or any hearing concerns, and no known concomitant disorder such as autism, attention deficit disorder or cerebral palsy.

The deaf group included five deaf children (three female) ranging from 6 years and 7 months to 11 years and 2 months ($M = 8$ years 6 months; $SD = 1$ year 9 months; Raven's IQ, $M = 91$; $SD = 17.46$). Four of the children were severely deaf (hearing loss > 70 dB in their better ear)

and one child was profoundly deaf (hearing loss > 90 dB). Based on parental report alone, none of children had any known concomitant disorders such as intellectual disability, attention deficit, or autism. All the children received auditory amplification: three wore cochlear implants and two children wore a hearing aid. None of the children had a deaf parent, and all deaf children communicated with the use of Sign Supported English.

The hearing group included five typically developed children (three female) aged between 6 years 10 months and 10 years 1 month ($M = 8$ years 2 months; $SD = 1$ year 3 months; Raven's IQ $M = 98$; $SD = 10.37$) and matched the deaf children's non-verbal ability and chronological age. Independent samples t-tests revealed no significant difference in age ($t(8) = .33, p = .75$) or non-verbal ability ($t(8) = -.77, p = .46$) between the groups. It was not possible to match participants on verbal ability because these measures are not standardised for a deaf population (Prezbindowski & Lederberg, 2003). The deaf children, however, performed within the average range on the British Sign Language receptive language test ($M = 101$; $SD = 14.07$) and the hearing control children scored within the average range on the British Picture Vocabulary Scale receptive language test ($M = 106.4, SD = 9.61$).

Demographic information is in Table 1.

Table 1. Demographic information and language characteristics of deaf and hearing children

Group	Sex	Age (years; months)	Non- verbal IQ	Standardised language (D: BSL; H: BPVS)	EVT (maximum score = 12)	Level of Deafness	HA vs. CI
Deaf	M	9; 0	110	123	11	Severe	HA
Deaf	M	7; 2	75	86	9	Severe	CI

Deaf	F	11; 2	100	102	12	Severe	CI
Deaf	F	8; 10	70	92	6	Profound	HA
Deaf	F	6; 7	100	102	10	Severe	HA
Hearing	M	8; 11	90	118	12		
Hearing	M	7; 7	95	103	10		
Hearing	F	10; 1	90	100	12		
Hearing	F	6; 10	100	115	11		
Hearing	F	7; 6	115	96	10		

Note. D = Deaf; H = Hearing; IQ = Intelligence Quotient; BSL = British Sign Language; BPVS = British Picture Vocabulary Scale; EVT = Emotion Vocabulary Test; HA = Hearing Aid; CI = Cochlear Implant

2.1.2 Adult raters

Thirty-five university students (22 female and 12 male), between 19 years and 6 months and 65 years and 1 month ($M = 30$ years 3 months; $SD = 11$ years) were recruited to rate the children's videos and performed the task individually in a laboratory. All participants were students in psychology courses at universities in the United Kingdom. They were all unpaid volunteers.

2.3. Materials and Procedure for assessing emotion production in children

2.3.1 Pre-tests

The Emotion Vocabulary Test (EVT; Dyck, Ferguson & Shochet, 2001) was used to prime the children to think of the emotions and to check their comprehension. This task involved asking the children to recall scenarios and provide examples of when they, or another person, experienced the emotion (e.g. "I was sad when my pet dog died"). Additionally, prototypical faces of different emotions were shown to the children to check they could recognize them.

When the pre-test concluded, the materials were removed from the table.

2.3.2 Voluntary Emotional Expressions, Social stories and Intentional Mimicry Tasks

The children were seated 60 cm 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 sat behind the laptop, facing the child. All children were filmed facing the camera. Each child was requested to perform three different tasks involving emotional expressions, and the order in which the children received each of tasks was counterbalanced across participants.

For Task one (Voluntary Expression), the experimenter explained that she was going to film 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 children were asked to produce the six emotion expressions once, in one of three randomized orders. 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 with the emotion facial expressions between 2-7 seconds.

For Task two (Signed stories), the materials consisted of 12 short stories of emotion-specific events presented in video format: This included two stories aimed at eliciting each of the six emotions. Five of the stories were based on Widen and Russell (2002) and seven stories were created for this study (stories are provided in the appendix). All stories were altered for ease

of translation into SSE. The order of stories was randomized across participants. Children were told that they would watch some videos of a person telling stories and would be asked to produce a facial expression showing how the main character in the story would have felt. To ensure the story had been understood, the children were also asked to explain why the character may have had those feelings. An example story was shown first to ensure that the instructions were clear. Once each story had finished, the experimenter asked the child in the same order to “show me with your face how [the main character] feel.”

For task three (Mimicry), the stimuli were clips of human faces selected from the Amsterdam Dynamic Facial Expression Set (ADFES; Van der Schalk et al., 2011). The six emotions investigated were displayed by two male and two female actors and each clip was edited and lasted for five seconds each, starting from a neutral pose to the apex of the expressed emotion. Three sets of six emotions were created mixing the male and female actors in each set. Children were initially shown three clips not included in the testing sets to ensure that the task procedure was understood. The children were asked to produce the same facial expression they had just viewed in the clip before moving to the next one. Each child was shown 18 clips in total, three of each of the six emotions tested and randomised for each participant.

2.4. Measurement of accuracy and intensity

2.4.1 Video processing

To obtain the final stimulus material all the videos were edited using the video editing software VirtualDub (VirtualDub 1.10.3). For the voluntary posed task 12 videos were created in total (six emotions x five deaf children, and six emotions x five hearing children). For the signed stories: 24 videos were created in total, (two for each of the six emotions x five deaf children, and two for each emotion x five hearing children). For the intentional

mimicry: 36 videos were edited in total, 18 videos (three for each of the six emotions x five deaf children, and three for each of the six emotions x five hearing children). Each video started just before the onset of each emotional expression and ended at the time the expression returned to a neutral state. In order to confirm the accuracy of the expressions, each video was analysed using the Noldus software FaceReader (version 4) at a rate of 5 frames per second and averaged every 0.5 of a second. This software is designed to classify emotions based on facial expressions according to the Facial Action Coding System (FACS; Ekman, Friesen & Hager, 2002). This analysis provides an objective measure of the children's ability to produce emotional facial expressions.

2.4.2 Human judgment of accuracy and intensity

The adult raters were informed that they were taking part on a study investigating children's production of emotional facial expressions but were kept blind to the study's hypotheses and the characteristics of the groups, although some amplification aids were visible the video clips. After providing consent, each participant was seated in front of a computer that showed all the videos and questions. After reading the instructions and indicating he or she was ready to start, one of the video clips of the emotional expressions was played, followed by a screen showing six emotion words (happiness, sadness, anger, fear, disgust and surprise) and were required to make a categorical judgement of each emotional expression by assigning one label from the short list that best represented the emotion displayed. Participants were then asked to rate the intensity (i.e. "how clear was the emotional facial expression"?) on a scale from 1 (not at all intense) to 5 (extremely intense).

The inclusion of intensity scale is important, as it has been shown to impact accuracy in recognition in typically developing populations, with higher levels of accuracy generally found at higher levels of intensity (e.g. Wingenbach, Ashwin & Brosnan, 2016; 2018), although recognition has been found to be harder at very high levels of intensity of facial

expression, and the body has been found to be important in aiding discrimination (Aviezer, Trope & Todorov, 2012). After a short pause, another clip was presented. All 180 clips were presented in a random order to each participant. When the participants finished all the video rating they were thanked and debriefed.

2.5. Data Analysis

The main strategy was focused on differences between groups but accounting the unbalanced nature of the data, as not all tasks had the same number of observations. Each of the videos was analysed on three ways. First, the data from the FaceReader software was analysed with a multilevel mixed-effects analysis model in which emotions (Level 1: Happiness vs. Sadness vs. Anger vs. Fear vs. Disgust vs. Surprise) was nested within tasks (Level 2: Voluntary expressions vs. Signed stories vs. Mimicry) and these were nested within groups (Level 3: Deaf vs. Hearing). This analysis was used because the software evaluated both groups with three tasks and six emotions. The emotion, group and task were fixed factors and the analysis used maximum likelihood estimation.

Secondly, each video was shown to human raters to investigate the accuracy of the identification of the intended emotional expression presented. This analysis was performed with a X^2 test for differences between the groups, on each emotion and task.

Finally, the intensity of the emotional expression of each video was analysed by the same raters as in the accuracy task. This analysis also had a mixed-effects analysis model in which emotions (Level 1) was nested within tasks (Level 2), which were nested within groups (Level 3) and finally nested within raters (Level 4). The emotion, group and task were fixed factors, whereas the rater was a random factor. This analysis includes raters evaluating both groups, doing three tasks with six emotions each. Maximum likelihood was also used in this analysis.

3. Results

3.1 Objective ratings of emotions

Each video was analysed using the software FaceReader (version 4). The software detects the features in facial expressions associated with emotions and transforms such values into ratings of the emotions of anger, disgust, fear, happiness, sadness, and surprise, ranging from 0 (the specific emotion 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 values obtained were averaged to create one score for each emotion displayed in each video and then averaged in each group creating one score per emotion in each task (Table 2).

Table 2: Means and standard deviations of FaceReader values of accuracy by Group and Task

	Voluntary Expressions		Signed Stories		Mimicry	
	Deaf	Hearing	Deaf	Hearing	Deaf	Hearing
Happiness	.68 (.36)	.82 (.09)	.76 (.22)	.88 (.08)	.81 (.12)	.73 (.41)
Sadness	.63 (.23)	.58 (.31)	.64 (.21)	.65 (.37)	.46 (.39)	.54 (.29)
Anger	.21 (.34)	.29 (.31)	.03 (.04)	.28 (.4)	.49 (.46)	.28 (.39)
Fear	.15 (.16)	.23 (.19)	.01 (.01)	.20 (.31)	.02 (.03)	.29 (.43)
Disgust	.41 (.33)	.14 (.17)	.34 (.38)	.10 (.13)	.18 (.29)	.41 (.34)
Surprise	.82 (.11)	.62 (.37)	.31 (.35)	.34 (.39)	.73 (.31)	.60 (.34)

Note: Standard deviations are in parentheses

Results revealed non-significant main effects of Group or Task ($F(1, 144) = .15, p = .69$, and $F(1, 144) = 1.77, p = .19$, respectively) but a main effect of Emotion was present, $F(5, 144) = 20.50, p < .001$. Results also revealed that the interactions between these factors were not significant, (Group x Emotion: $F(5, 144) = .95, p = .46$; Group x Task: $F(2, 144) = .44, p = .64$; and Task x Emotion: $F(10, 144) = 1.26, p = .14$. Finally, the Group x Task x Emotion interaction was not significant, $F(10, 144) = .92, p = .51$. A graphical representation is in

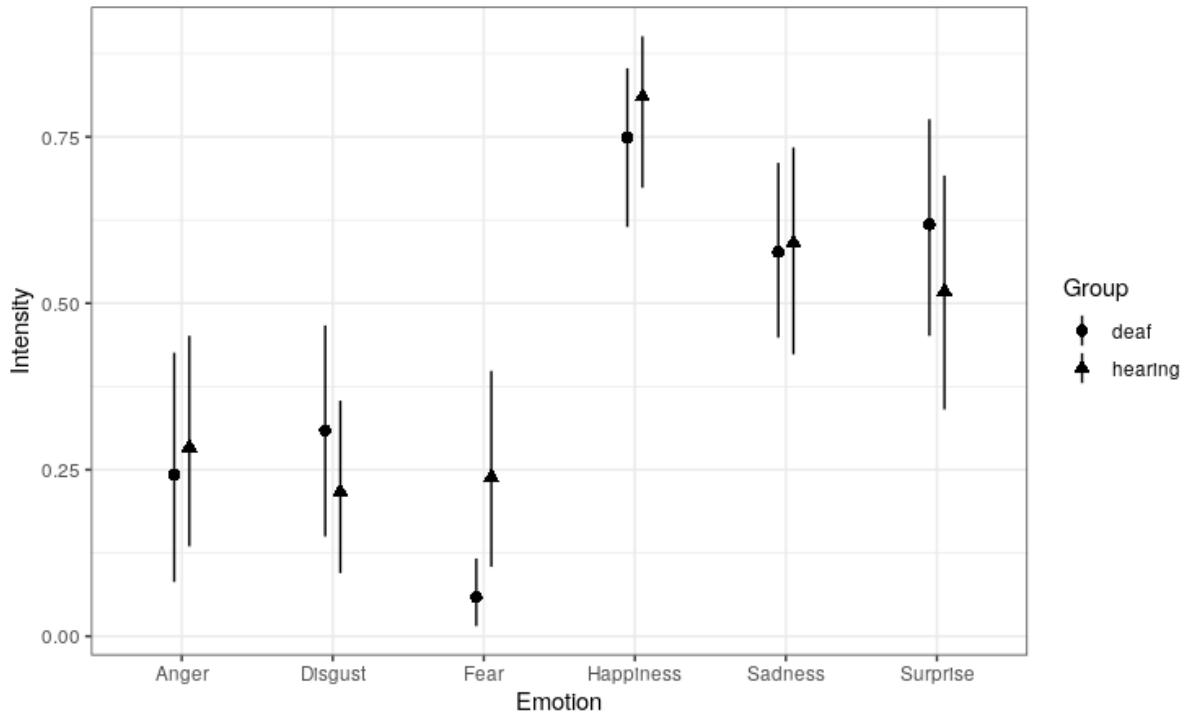
Figure 1. Further pairwise *t*-tests with Bonferroni adjustments focused on differences between emotions revealed that happiness, sadness and surprise were not significantly different from each other but significantly higher than anger, fear and disgust, which did not differ significantly (Table 3).

Table 3: FaceReader differences on accuracy of each emotion pair recorded

Emotion pair	<i>t</i> (29)	adjusted <i>p</i> value
Anger – Disgust	0.01	.99
Anger – Fear	1.42	.99
Anger – Happiness	-6.46	.001***
Anger – Sadness	-4.10	.005**
Anger – Surprise	-4.40	.002**
Disgust – Fear	1.65	.99
Disgust – Happiness	-6.06	.001***
Disgust – Sadness	-4.24	.003**
Disgust – Surprise	-3.90	.008***
Fear – Happiness	-8.80	.001***
Fear – Sadness	-5.75	.001***
Fear – Surprise	-5.20	.001***
Happiness – Sadness	2.84	.123
Happiness – Surprise	2.48	.250
Sadness – Surprise	0.20	.99

Note: *** $p < .001$, ** $p < .01$, * $p < .05$. Significant differences are based on the adjusted *p* values ($.05/15 = p < .003$)

Figure 1: FaceReader accuracy values of Emotions by Group



Note: lines indicate standard errors

3.2 Adult ratings of expressions of emotions

3.2.1 Accuracy

To investigate the accuracy in recognition of the emotion expressions the proportion of agreement between the intended expression of the children and the emotion identified by the decoders was calculated (coded as: 1 = correct, 0 = incorrect). A chi-squared test comparing the groups was calculated for the proportion of correct responses in each emotion and each task. Results revealed that the expressions of deaf children were identified correctly to a similar degree than those of hearing children. The expressions of hearing children were identified significantly more accurately only on happiness (signed stories), and disgust (signed stories and voluntary expressions). There were no significant differences in any of the emotions for the mimicry task (Table 4).

Table 4: Mean and standard deviation of intensity, proportion of accuracy of adult ratings, and chi-squared test of independence by emotion, group and Task

	Intensity			Accuracy		
	Deaf	Hearing	Difference <i>t</i> (df)	Deaf	Hearing	$\chi^2(1)$
Task 1						
Happiness	3.09 (0.98)	2.69 (1.02)	<i>t</i> (174) = 3.95***	95.40	96.60	0.30
Sadness	2.67 (1.19)	2.30 (0.8)	<i>t</i> (174) = 3.64***	85.70	78.30	3.27
Anger	3.43 (1.15)	2.93 (1.01)	<i>t</i> (174) = 4.20***	72.60	46.30	13.37***
Fear	3.55 (0.89)	3.06 (1.13)	<i>t</i> (174) = 4.78***	66.90	31.40	43.94***
Disgust	3.46 (1.00)	2.9 (0.97)	<i>t</i> (174) = 5.98***	58.90	72.60	7.30**
Surprise	3.63 (1.08)	3.11 (1.08)	<i>t</i> (174) = 4.23***	86.90	66.30	17.80***
Task 2						
Happiness	3.3 (1.12)	2.72 (0.98)	<i>t</i> (349) = 7.34***	76.86	93.43	37.99***
Sadness	2.96 (1.02)	2.56 (0.80)	<i>t</i> (349) = 5.82***	93.14	90.86	1.24
Anger	3.45 (1.07)	2.64 (1.01)	<i>t</i> (349) = 10.20***	56.86	44.57	10.57***
Fear	3.15 (1.06)	2.75 (0.93)	<i>t</i> (349) = 5.36***	70.86	47.71	38.83***
Disgust	3.51 (0.91)	3.24 (1.02)	<i>t</i> (349) = 3.79***	77.71	78.29	0.03
Surprise	3.8 (0.86)	3.16 (0.94)	<i>t</i> (349) = 9.51***	50.57	41.43	5.89*
Task 3						
Happiness	3.04 (0.98)	2.54 (0.87)	<i>t</i> (524) = 9.47***	91.81	92.95	0.49
Sadness	2.80 (0.88)	2.46 (0.92)	<i>t</i> (524) = 6.38***	69.71	73.52	1.87
Anger	2.98 (0.89)	2.45 (0.83)	<i>t</i> (524) = 10.90***	58.29	63.05	2.49
Fear	3.13 (0.84)	2.60 (0.88)	<i>t</i> (524) = 10.92***	52.76	49.71	0.98
Disgust	2.84 (0.97)	2.84 (0.92)	<i>t</i> (524) = .07	62.29	73.52	15.21***
Surprise	3.34 (0.89)	2.88 (0.95)	<i>t</i> (524) = 8.64***	79.24	79.62	0.02

Note: *** $p < .001$, ** $p < .01$, * $p < .05$, Standard deviations are in parenthesis

3.2.2 Intensity

The ratings for the intensity of the emotions displayed was analysed with a mixed-effects model (Group x Task x Emotion). Results revealed significant main effects of Group ($F(1, 34) = 216.34, p < .001$), Task ($F(1, 138) = 46.02, p < .001$), and Emotion ($F(5, 1030) = 102.33, p < .001$). These effects were qualified by several significant interactions: Group x Task ($F(1, 138) = 1.31, p < .001$), Group x Emotion ($F(5, 1030) = 12.62, p < .001$), and Task x Emotion ($F(5, 1030) = 15.46, p < .001$). A significant Group x Task x Emotion interaction was also present, $F(5, 1030) = 4.30, p < .001$. Separate analysis in each task

revealed significant Group x Emotion interactions on signed stories and mimicry ($F(5, 340) = 8.02, p < .001$; and $F(5, 340) = 10.58, p < .001$, respectively) but not for the voluntary expressions task ($F(5, 340) = .48, p = .80$). Separate analysis comparing each emotion between the deaf and hearing children with paired samples t -tests revealed that the expressions of deaf children were rated more intense than those of hearing children (means, standard deviations and t test results are in Table 3, Figure 2).

Figure 2. Adult raters intensity values of Emotions by Task by Group



4. Discussion

The ability of severely-profoundly deaf children of hearing parents to produce facial expressions of emotions was examined using three different tasks: voluntary posed expressions of emotions, responding to signed stories, and the intentional mimicry of facial expressions. The objective ratings of emotions using the FaceReader software revealed no significant differences between deaf and hearing children's expressions across the three tasks. While the adults rated the expressions of deaf children to be mainly as accurate to those of the hearing children, the deaf children were judged as displaying emotions with greater intensity. Therefore, the results showed the deaf children were able to accurately produce emotion expressions that were readily recognized by others.

Before considering the implications of these findings, it is first important to briefly consider why differences emerged in the adult subjective ratings while no differences were found in group performance as measured by the FaceReader software. The FaceReader software uses 'prototypical' configuration of facial expressions rated according to facial action units (FAU), meaning that these results suggest that the deaf and hearing children were developmentally at a similar level in being able to engage facial muscles to pose facial expressions on demand. Both groups of children were able to more accurately produce the prototypical expression of happiness in comparison to the negative emotions of fear, disgust and anger, which is consistent with previous studies investigating emotion encoding abilities in typically developed children (e.g., Grossard et al., 2018). This finding is also in line with Ekman's (1985) account explaining that the muscle movements for the negative emotions of fear, disgust and anger, are harder to control consciously.

Furthermore, the comparatively high accuracy ratings of the human judges draw attention to a methodological strength of including subjective ratings in this study. Human raters were able to utilise non-prototypical additional dynamic emotion cues, such as cowering backwards with fear and the tongue protrusion for disgust, and therefore were able

to provide a more accurate measure of the deaf and hearing children's understanding of emotion (De Gelder, Snyder, Greve, Gerard & Hadjikhani, 2004). This is supported by research that has found that body cues are important in aiding emotion discrimination, particularly at peak intensities of emotion (Aviezer et al., 2012).

The results of the present study measuring the ability of deaf children to accurately produce facial expressions of emotion contrasts with some research suggesting a delay in the ability to mask emotions (Hosie et al., 2000) and in their understanding of emotion stories (Gray et al., 2001). This paradox may appear even more evident in the current signed stories task, whereby the ability to recognise an emotion from the story would also be required to accurately produce the emotion, again the deaf children showed no deficit. The participants in Gray et al.'s (2001) were similarly severe-profoundly deaf, and communicated in a combination of SSE and BSL. It is possible that deaf children found it easier to identify the emotions in our stories as they were presented in SSE, whereas interpreting the stories from Gray and colleagues' (2001) study required divided attention between both a signing adult telling the story and a picture. Furthermore, the findings in the present study are also consistent with recent research showing accurate emotion production in a small group of severe-profoundly deaf children communicating in BSL (both native and non-native), as measured when telling a story narrative (Denmark et al., 2019).

While deaf children were judged by the adults as mainly being as accurate as the hearing children on the three tasks, it is important to recognise that the deaf children were less accurate in their production of disgust for both the signed stories and voluntary expressions. Deaf children have been shown to make more errors in recognising disgust than their hearing peers (Jones et al., 2018). Since the ability to recognise and label emotions is associated with developing 'emotion scripts' that emerge through conversation with emotion content (Widen & Russell, 2003), it may be that deaf children have a less well-developed

concept of disgust as a result of reduced opportunity to discuss and overhear conversations about emotions (Jones et al., 2018; Widen, 2013). It is also possible that no differences for disgust were found between the groups of children for the intentional mimicry task because they had direct visual cues to follow.

The deaf children were also rated as displaying emotions with great intensity by the adults, suggesting that despite emotion expressions arguably being universal, there are some individual differences on the intensity of emotions expressed for specific context and /or culture/language-specific prescriptions (Ekman, 1993). Deaf children may be more expressive than hearing children through their use of sign language for both linguistic markers as well as to convey emotion, which could refine and enhance their expressive knowledge. This theory is supported by previous research with hearing individuals experienced in American Sign Language who were rated as being more adept at encoding facial expressions of emotion than individuals with no experience of sign language (Goldstein et.al, 2000). Another possibility is that the use of facial expressions in language has led them to produce more exaggerated facial expressions to avoid any ambiguity when communicating with others. In addition to experience of sign language, level of deafness may also be an important factor, as severe to profoundly deaf individuals, such as the children in the present study, would be unable to detect emotion through the tone of voice. A recent study of emotion recognition in profoundly deaf early-signing adults also found that for the emotion, disgust, a greater level of intensity was required to achieve expression recognition compared with hearing non-signers (Stoll et al., 2019). It is possible that for deaf individuals intensity is important, as they are reliant on visual cues to disambiguate disgust from other similar facial expressions such as anger or confusion.

Of particular note is that deaf children express the negative emotion of anger with

greater intensity – an emotion that hearing children in some western cultures are often encouraged to subdue, as it is often considered to be socially unacceptable to display angry outbursts (Lewis et al., 1987). 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. This perhaps points to a cultural difference in display rules, in the sense that deaf children may naturally produce a greater level of facial expression of emotion. These findings arguably highlight the importance of considering the influence of culture in facial expression production, as well as facial expression processing (Stoll et al., 2019), valuing difference between levels of expressiveness across cultures. This marks a shift in perspective from the traditional focus on the deficit model of hearing loss in the field of emotion processing (Stoll et al., 2019). Importantly, Deafness is a culture, which includes rights in terms of the recognition of its linguistic identity. While these results need to be confirmed with larger samples of native and non-native signers across varying levels of deafness, in both deaf and hearing populations it appears that clarity of emotional expression is important to deaf children's display rules.

The results from the intentional mimicry tasks showing deaf children produced more intense emotional expression as well as being as accurate as hearing controls, is encouraging given the socially facilitative role of ability to recognise and imitate a response to others (Fischer & Manstead, 2008). However, questions remain as to whether deaf children spontaneously mimic emotions, given that in everyday life mimicry occurs rapidly and without effort. For example, children with ASD have been found to be impaired on spontaneous but not voluntary mimicry of emotional expressions (McIntosh, Reichemann-Decker, Oberman et al., 2009; Winkielman & Wilbarger, 2006). 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 ToM tasks (Meltzoff & Gopnik, 1993). Yet the level of expressiveness displayed by the deaf children and clarity in their expression of emotion, 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).

It is important to note that deaf children all used a mixture of oral and sign language to communicate (sign-supported English). Therefore, it is unclear whether differences in emotion production between the deaf and hearing groups would be more evident in deaf children reliant on communicating in sign language only. Future studies comparing both deaf and hearing native signers and non-signers on emotion production would be needed to directly infer the role of sign language. In addition, the expressions were taken from a very small sample of deaf and hearing children therefore caution is raised surrounding the generalizability of the results. A further limitation is that some of the hearing devices were visible on the deaf children, meaning that the raters were not blind to the hearing status of the child. However, adult raters were only told the study's hypotheses once the task had been completed. In addition, data on the age of hearing amplification was missing from the study: a factor which has been shown to have a significant impact on language development for deaf children, which in turn may be an important influence on facial expression processing. Yet BSL Receptive language scores were included in the study as a measure of language ability, and the results suggest that all the deaf children were within the average range.

The use of adult raters in the study does not rule out the possibility that children would rate the deaf and hearing groups of children differently. Therefore, given deaf children

have been reported as showing social difficulties linked to emotion understanding (Hoffman, Quittner, & Cejas, 2014), how their peers rate their emotional expression could also be an important consideration for future studies.

The deaf children's ability (in this study) to produce clear facial expressions of emotion is encouraging given its importance in everyday social interactions (Fischer & Manstead, 2008). The current findings are also consistent with recent research showing accurate emotion production measured when telling a story narrative in a small group of deaf children communicating in BSL (both native and non-native) (Denmark et al., 2019). While these results need to be confirmed with larger samples of native and non-native signers across varying levels of deafness, in both deaf and hearing populations it appears that clarity of emotional expression is important to deaf children's display rules. Future studies could consider the emotion production of spontaneous facial expressions of both deaf and hearing children in more naturalistic contexts.

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Emotion	Story
Happiness	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
Happiness	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.
Sadness	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.
Sadness	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
Anger	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 careful." But the boy knocked it over anyway. Ben wanted to yell at that boy and hit him
Anger	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
Fear	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.

Fear	Ann was walking home. It was very dark. She saw shadows moving. The wind was blowing hard. She started to run.
Disgust	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.
Disgust	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.
Surprise	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!'
Surprise	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.

*Adapted from Widen and Russell (2002);

** Piloted on 53 psychology students (39 female, 14 male) in emotion elicited by each story