Emotional Facial Expressions Communicated to Typically Developing and Autistic Children: Differences in Expression Intensity and Complexity

Author Note:

This thesis is submitted in partial fulfilment of the Honours Degree of Bachelor of Psychological Science (Honours)

Word Count: 9,265

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Abstract

Children's knowledge of emotional facial expressions develops slowly with age. Resultantly, when interacting with very young children, others often perform infant-directed modifications, simplifying and exaggerating their actions. However, the attainment of emotional knowledge, including from facial expressions, follows an alternate trajectory in Autism Spectrum Disorder (ASD). Despite symptoms of ASD often appearing in early childhood, it is unknown whether others adapt their emotional facial expressions differently for atypically versus typically developing children. The present study analyses the emotional facial expressions appearing in the SAYCam video corpus, a naturalistic, longitudinal dataset of infant-perspective films from one autistic and two typically developing children. Specifically, the intensity and complexity of these expressions is investigated. Facial expression analysis software identified the expressions of surprise and fear were particularly exaggerated, while joyful expressions were significantly less intense, for the autistic relative to the typically developing children. Furthermore, the direction and rate of intensity change over time for most emotion categories observed by the autistic child were opposite those observed by the typically developing children. Finally, more complex expressions were seen by the autistic child, but neither group saw changes in expression complexity over time. These findings have implications for understanding the social world from an autistic individual's point of view, and guide the field towards the inclusion of a child's interaction partners into interventions for ASD.

Keywords: Autism Spectrum Disorder, emotional facial expressions, children, intensity, complexity

Declaration

This thesis contains no material which has been accepted for the award of any other degree of diploma in any University, and, to the best of my knowledge, this thesis contains no material previously published except where due reference is made. I give permission for the digital version of this thesis to be made available on the web, via the University of Adelaide's digital thesis repository, the Library Search and through web search engines, unless permission has been granted by the School to restrict access for a period of time

Contribution Statement

In writing this thesis, my supervisor and I collaborated to generate potential areas of research interest. I then conducted the literature search and selected appropriate hypotheses to be tested with my supervisor's confirmation. Myself, my supervisor, their research assistant, and three other Honours students also analysing the current dataset collaborated to pre-register the project and upload the study details into the Open Science Framework. My supervisor and their research assistant set up the iMotions software for coding, then I and the three other Honours students using this dataset coded videos individually. My supervisor's research assistant exported the data from iMotions, then cleaned and formatted the data into a usable .csv file. I then completed and interpreted the data analysis, with guidance from my supervisor where difficulties were encountered. I wrote all up aspects of the thesis.

Emotional Facial Expressions Communicated to Typically Developing and Autistic Children: Differences in Expression Intensity and Complexity

The acquisition of emotional knowledge is a key component of a child's development, allowing children to comprehend the world around them and interact with others in social contexts. One way emotions are conveyed is through facial expressions, which permit us to express our own or evaluate others' internal states almost instantly with little cognitive effort. Despite the utility of this knowledge at all stages of life, children's understanding of emotional facial expressions develops slowly and gradually over time (Widen, 2013). Until pre-school age, children initially sort emotional facial expressions into two broad, valence-dependent categories of 'feels good' or 'feels bad', which progressively diversify until recognition of more complicated emotions is possible, usually in the teen years (Widen & Russell, 2008, Widen, 2013, Chronaki et al, 2015). Typically, children first learn to differentiate facial expressions of happiness, sadness, and anger, later mastering the recognition of more complicated emotions like disgust and fear (Herba et al, 2006, Widen and Russell, 2008). These more intricate emotions require the ability to understand and interpret others' thoughts, knowledge of the behavioural consequences of expressing such emotions, or other distinguishable social cues children may only acquire with age and experience (Widen, 2013).

Though the development of such knowledge spans most of childhood, even very young infants have some understanding of emotional facial expressions. By three and a half months, infants can differentiate between happy and sad facial expressions, and distinguish which facial expression matches their corresponding emotional vocal expressions (Kahana-Kalman & Walker-Andrews, 2001). By four months, infants may recognise when an emotional exchange differs from their expectations. When such an interaction diverges from their predictions, infants exhibit greater affective responsiveness and interest towards their interaction partner (Montague & Walker-Andrews, 2001). Additionally, infants may either increase or decrease their looking time depending on the unexpected emotion portrayed (Montague & Walker-Andrews, 2001). By seven months, infants can distinguish angry, happy, interested, and sad emotional facial expressions, as demonstrated by preferential looking paradigms (Soken & Pick, 1999).

Autism Spectrum Disorder

However, attainment of emotional knowledge follows a markedly different trajectory in atypically developing children. One such atypicality is Autism Spectrum Disorder (ASD), a neurodevelopmental condition defined by impairments in social communication and interaction, with restricted and repetitious activity, behaviour, or interest patterns (American Psychiatric Association, 2013). These deficits present from early childhood, and regularly impair daily functioning (American Psychiatric Association, 2013). Emotion-related deficits are common symptoms of ASD, affecting multiple domains of emotional expression and understanding (Begeer et al, 2008, Philip et al, 2010, Fridenson-Hayo et al, 2016). Resultantly, those diagnosed with the disorder frequently experience difficulties in social-emotional reciprocity, non-verbal communication, navigating social relationships, and making social-related judgements about others, and more (Philip et al, 2010, American Psychiatric Association, 2013). Throughout this thesis, to respect the autonomy and self-identity of those diagnosed with the disorder, identity-first language will be used when referring to ASD.

Emotional facial expressions remain a useful form of communication for autistic individuals, however their skills in this domain are often impaired. Though the literature on deficits in emotional facial expression-related deficits in ASD can be mixed (see Begeer et al, 2008, Keating & Cook, 2020), several consistent deficits have been identified. While typically developing children see their facial expression recognition skills increase gradually over their lifespan (Widen & Russell, 2008, Widen, 2013), such skills in autistic individuals remain relatively stagnant and show little improvement beyond late childhood (Rump et al, 2009). Resultantly, difficulties in recognising emotions from facial expressions in ASD may increase with age, as autistic individuals experience downstream developmental consequences and trail behind their typically developing peers (Lozier et al, 2014, Keating and Cook, 2020). Such deficits have been identified not only in recognition of more complicated emotional facial expressions, such as disappointment, excitement, and shame, but also of the six 'basic' emotions of anger, disgust, fear, happiness, sadness, surprise (Law Smith et al, 2010, Philip et al, 2010, Fridenson-Hayo et al, 2016, Loth et al, 2018). However, happiness may be the emotion least affected by the expression recognition deficits in ASD (Uljarevic & Hamilton, 2013, Lozier et al, 2014).

Autistic individuals also demonstrate difficulties in producing emotional facial expressions, with meta-analytic evidence suggesting moderate deficits in this area compared to typically developing people (Trevisan et al, 2018). Autistic persons produce emotional facial expressions less frequently and for shorter amounts of time, and are likely less expressive overall than typically developing persons (Stagg et al, 2014, Trevisan et al, 2018, but see Sheppard et al, 2015). Furthermore, the emotional facial expressions of autistic individuals are visually different from those produced by their typically developing peers. For instance, their facial expressions are more intense and but also more ambiguous, less accurate and natural, and generally harder for both human observers and facial expression recognition software to recognise (Faso et al, 2015, Brewer et al, 2016, Grossard et al, 2020). However, such deficiencies in emotional facial expression production appear to decrease with age, potentially due to accumulating life experiences and knowledge of societal norms in facial expression production (Trevisan et al, 2018).

Limitations of the Current Literature

Emotional facial expressions have tremendous social utility for all people. Furthermore, the use of emotional cues during social exchanges is a reciprocal process multiple parties partake in. Most investigations of both typically developing and autistic children's emotional knowledge, however, have used laboratory-based designs not involving interaction with other people (see Begeer et al, 2008, Widen, 2013). Resultantly, the literature may be at best missing, or at worst misrepresenting, children's comprehension of emotional facial expressions. Given emotional facial expressions are mostly used in social contexts, socially interactive paradigms would provide the most realistic depiction of how children develop the skills required to understand and utilise emotions. Considering this, Fong and colleagues (2020) asked typically developing children to guess the object inside a box from the emotion an experimenter expressed upon opening it, and to complete a facial emotion labelling task from static photos. While children's ability to use the experimenter's expression to determine the box's contents increased with age, their performance in the labelling task was heavily dependent on the emotion presented, and showed no changes with age (Fong et al, 2020). Likewise, Begeer and colleagues (2006) asked young autistic boys and controls to sort photos of smiling and frowning facial expressions. While the autistic boys initially performed less accurately than controls, their performance increased when specifically asked to make 'socially relevant' judgements (i.e., considering how they expected the person to act in the future, Begeer et al, 2006).

Similarly, contextual information is particularly influential in children's developing knowledge of emotional facial expressions. Even laboratory-based paradigms with socially interactive tasks often require children to interact with unfamiliar people like researchers or actors. However, person familiarity can facilitate a child's emotional understanding. Typically developing infants as young as three and a half months can distinguish between the emotional facial expressions demonstrated by their mothers earlier than for unfamiliar women (Kahana-Kalman & Walker-Andrews, 2001), and look longer towards the expressions of parents with whom they spend more time with (Montague & Walker-Andrews, 2002). Hence, young children's understanding of emotional facial expressions may be closely tied to variables within the people they interact with most. Therefore, family dynamics and patterns of parent-child involvement likely play a role in infants' understanding of emotional facial expressions.

A third domain where many studies fall short is their use of static emotional facial stimuli high in intensity and prototypicality (Herba et al, 2006, Law Smith et al, 2010, Song & Hakoda, 2018). Naturally produced facial expressions are intrinsically dynamic and lower in intensity, and appear for shorter periods of time. A failure to consider such variables when selecting facial expression stimuli may obscure more intricate details of children's emotion knowledge development. For instance, Herba and colleagues (2006) found while increasing the intensity of facial expression stimuli improved emotion recognition in typically developing children, increasing their intensity above 50% did not facilitate better emotion recognition. Additionally, when investigating individual emotion categories, typically developing children appear to first learn to distinguish happy facial expressions at lower intensities by five years old (Gao et al, 2009, 2010). Meanwhile, their sensitivity to varying intensities of disgust, surprise, and fear improve between five and ten years, while detection of anger at more subtle thresholds may only be achieved after ten years old (Gao et al, 2009, 2010). For sad facial expressions, however, some evidence suggests adult-like levels of low intensity sadness recognition are achieved by five years old, others only after ten years old

(Gao et al, 2009, 2010). However, using high intensity stimuli would have masked these developmental trajectories from being identified.

Nonetheless, in those diagnosed with ASD, the intensity of emotional facial expressions is much more influential. Autistic individuals have greater difficulty than their typically developing peers in recognising emotional facial expressions at lower intensities. Additionally, they may also require more intense expressions to correctly identify emotions than their typically developing peers (e.g., Wong et al, 2012). However, whether these intensity-related deficits are emotion-specific or more global is debated. Law Smith and colleagues (2010) identified when viewing video clips of faces conveying the six basic emotions from 20% to 100% intensity, autistic adolescents identified only disgust, anger, and surprise less accurately than controls. Yet, while disgust recognition was impaired at all intensities, surprise and anger recognition were only diminished at lower intensities (Law Smith et al, 2010). Similar results were observed by Song and Hakoda (2017), who found autistic individuals needed emotional facial expressions of higher intensities to correctly recognise anger, disgust, and fear in particular. Contrastingly, Rump and collaborators (2009) noted when viewing emotional facial expression stimuli at 25% intensity intervals, autistic children successfully identified all the emotions assessed, but required at least one intensity level higher than typically developing children to do so (Rump et al, 2009). However this deficit manifests, difficulties in recognising more subtle facial expressions appears a notable characteristic of ASD.

The ignoration of expression intensity has likely contributed to the mixed literature on emotion-related deficits in ASD. Using only ‘full-blown’ emotional stimuli, experiments may lack sensitivity to detect group differences, or diminish group differences by removing demands autistic individuals usually face when processing affect while socialising (e.g., time or attentional constraints) (Wong et al, 2012, Song & Hakoda, 2018). A recent study using more naturalistic variables better resembling realistic social interactions, such as short stimuli presentation time, confirmed sizeable deficits in emotional facial expression recognition in ASD (Loth et al, 2018). However, most studies of emotion-related deficits in ASD are still conducted in laboratories. Therefore, the emotion development literature requires investigations better assessing what children see in their day-to-day life, while also considering various external factors.

Role of the Social Environment in Children's Emotional Development

To achieve this, the field should turn its focus to investigating children's social environment, especially their familial or home environment. The expressivity of a child's family appears particularly influential in their emotional development. Infant positive affect has been strongly linked with parental and familial expressions of positive affect, with genetics contributing little to this effect (Planalp et al, 2016). Some investigations have also found children's overall emotional expressiveness is associated with both the family's and the child's positive expressivity, all the way from infanthood to adolescence (Halberstadt & Eaton, 2002). Comparatively, others have concluded toddlers' emotional expressivity and understanding are more associated with only their primary caregiver's level of expressivity and impulse strength (Ogren & Johnson, 2021). However this association manifests, demonstrating greater emotional responsiveness towards children allows them to learn about and understand emotions more readily.

Recognising the social environment's developmental importance, older individuals regularly adapt their behaviours when communicating to and interacting with infants and young children. By using a form of communication distinct from that used with other older people, termed 'infant-directed modifications', individuals attempt to enhance and scaffold the child's social experience. Such modifications are also utilised regardless of the gender of the infant’s interaction partner (Rutherford & Przednowek, 2012). Infant-directed action, for instance, is characterised by simpler motions, higher enthusiasm, increased eye contact with the infant, plus greater interaction and repetition (Brand et al, 2002, Brand et al, 2007). These simplified movements are typically slower than those demonstrated to adults (van Schaik et al, 2018), and utilise a greater range of motion performed in closer proximity to the infant (Brand et al, 2002). Infant-directed action emphasises the structure and consequences of actions, and serves to enhance and maintain an infant’s attention while encouraging imitation (Brand et al, 2002, Brand & Shallcross, 2008, Koterba & Iverson, 2009, Williamson & Brand, 2014). Notably, use of infant-directed action changes with infant age. By the time infants reach thirteen months of age, parents are performing shorter but more frequent gazes towards their child, and are more likely to exchange objects with the child (Brand et al, 2007).

Infant-directed modifications also exist in other modes of communication, including facial expressions. Though the focus on child-directed facial expressions is more recent, several expressions produced only towards infants have been identified. These include expressions of love and concern with puckered lips pulled slightly apart, positively-valenced ‘surprise’ or amazement expressions with raised brows, stretched open mouth, and slight smile, and exaggerated joyful expressions with a slightly open mouth and raised cheeks (Chong et al, 2003). The use of such exaggerated expressions attracts more attention from the child than when adult-directed facial expressions are utilised. Infants show consistent preferential looking towards infant-directed faces, even when presented in silence or with adult-directed speech (Kim & Johnson, 2014). Though parents would decrease their use of such modifications as the child’s emotional knowledge grows, the exact mechanisms of how this occurs is currently unknown.

Nonetheless, social interaction is a two-way street. Various characteristics of one's interaction partner will therefore influence how one behaves towards the other person. Consequently, because of their social-emotional deficits, autistic individuals are perceived and interacted with in a markedly different fashion to their typically developing peers. Autistic individuals are consistently rated lower by typically developing others on several aspects of social favourability, such as willingness to interact with, likeability, and empathy (Sasson et al, 2017, Alkhaldi et al, 2019, DeBrabander et al, 2019). Even autistic children are rated lower by their typical developing peers on several features of friendship, such as kindness, trustworthiness, and the typically developing child's desire to play with or befriend them (Stagg et al, 2014). Such perceptive differences may occur from typically developing individuals' 'mind-blindness' towards autistic persons, struggling to read and infer their state of mind, thus evaluating them more negatively (Edey et al, 2016, Alkhaldi et al, 2019). For instance, when interpreting control and autistic adults' behaviour in various social situations, typically developing raters made significantly more conjectures about the internal states of autistic participants than controls, likely due to difficulties in interpreting their responses (Sheppard et al, 2015). However, it is not yet known how early in a child's lifespan these perceptive differences appear. Additionally, most research in this area has focussed on first impressions of autistic others, hence we know little about how these perceptive differences may arise for those most familiar with the autistic child. While some studies have identified mothers use compensatory interaction styles in play settings with both familiar and unfamiliar autistic young children (Meirsschaut et al, 2011), these have only been identified in controlled environments.

Visibly, there remain several holes in our understanding of children's emotional development and related child-directed modifications. Firstly, most research on ASD has sampled only school-aged children and adults, though symptoms of ASD often appear in early childhood (American Psychiatric Association, 2013). Secondly, considering much of the emotional development research has utilised laboratory-based paradigms, the relevance of the social environment needs to be further integrated. Finally, there has been less of a focus on infant-directed facial expressions in general, and even less on how adults adapt their behaviours specifically to typically versus atypically developing children. Therefore, exploration of infant-directed facial expressions to this population is warranted.

The Current Study

One promising method of exploring these relationships is by using ‘head-cameras’. Infants don head-mounted cameras fitted to accessories like headbands or hats, allowing for recording of audio-visual data from the infant’s perspective. Though a relatively new method of research, preliminary findings using head-cameras provide a new outlook on infants’ visual experience. For instance, head-cameras have revealed by three months old, infants are exposed to faces for up to a quarter of their waking hours (Sugden et al, 2014, Sugden & Moulson, 2019). Of these faces, the majority belong to the infant’s primary caregiver, or are mostly female, adult-aged faces of the same race as the infant (Sugden et al, 2014). By eleven months old, however, head-cameras have shown the frequency of faces in infants’ view has decreased (Jayaraman et al, 2015). Nevertheless, faces seen at this stage are close in proximity to the infant, and are visually large with both eyes visible (Jayaraman et al, 2015). Head-cameras are also beginning to be used in examining the social environment of autistic children specifically. For example, these technologies have shown parents of autistic children monitor their child’s face more closely, and use significantly more gestures and scaffolding behaviours to enhance their child’s perceptive experiences in socially interactive contexts (Yoshida et al, 2020).

The current study utilises the SAYCam video corpus, a longitudinal dataset of infant-perspective head-camera videos, to investigate the perceptual experiences of two typically developing children and one autistic child, who was diagnosed shortly after filming was terminated (Sullivan et al, 2021). Specifically, the use of infant-directed emotional facial expressions for the typically and atypically developing children, and their use with increasing child age, and investigated. Following prior research, emotional facial expression intensity is tested, along with an exploratory inquiry into expression complexity. Not only does the literature require more investigations of the complexity of infant-directed communication (Kim & Johnson, 2013), there is also potential for recognition differences of compound emotions in ASD (Du et al, 2014). Therefore, it is hypothesised:

1. The emotional facial expressions conveyed to the autistic child would be (a) more intense and (b) less complex than those expressed to the typically developing children across the lifespan.
2. The emotional facial expressions communicated to typically developing children would become a) less intense and b) more complex over time.
3. The emotional facial expressions communicated to autistic child would not change in a) intensity or b) complexity over time.

Methods

The current thesis is part of a larger study assessing the emotional facial expressions communicated to young children, and has been pre-registered. The pre-registration can be accessed at https://osf.io/z24e9/?view_only=52aa83939af0431ab8dc395b8210f587.

Relevant ethics approval was granted for initial collection of the SAYCam data by the ethics review boards at the relevant establishments (see Sullivan et al 2021). Upon termination of data collection, Sullivan and colleagues (2021) uploaded the dataset to Databrary, an online data management and storage system. Researchers can then download the data to perform secondary analyses on the videos. For the current study, legal access to the SAYCam data corpus was granted by Databrary. However, as this thesis provides a secondary analysis of an existing dataset, the University of Adelaide ethics board confirmed no additional approval was required.

Participants

As described in Sullivan et al. (2021), three English-speaking families, of whom the mothers were academic researchers in schools of psychology, participated in data collection. One child from each family – [redacted], [redacted], and [redacted] – wore head-cameras from 6 to 32 months old (*M* = 17.7 months) (Sullivan et al, 2021). [redacted], a male infant who lived in Adelaide, South Australia, wore a head-camera from 6 to 30 months old (Sullivan et al, 2021). At three years old, six months after termination of data collection, [redacted] was diagnosed with ASD (Sullivan et al, 2021). [redacted], a female infant who resided in San Diego, California, USA, and Saratoga Springs, New York, USA, wore a head-camera from 8 to 31 months old (Sullivan et al, 2021). [redacted], a male infant who lived in Saratoga Springs, wore a head-camera from 7 to 24 months old (Sullivan et al, 2021). Data collection for [redacted] and [redacted] took place from 2013 to 2015, while data collection for [redacted] took place from 2018 to 2020 (Sullivan et al, 2017).

All individuals whose faces or voices were recorded provided written informed consent or verbal assent for their videos to be included in the dataset (Sullivan et al, 2021). Furthermore, all clips were inspected to ensure ethical content before their initial release (Sullivan et al, 2021).

Apparatus and Materials

As described in Sullivan et al. (2021), infant-perspective videos were filmed with a Veho MUVI Pro micro DV camera. The camera was fitted with a wide-angle fish-eye lens and attached to a headband, allowing it to sit at the infant's eye level (Sullivan et al, 2021). The head-camera had a viewing angle of 109 by 70 degrees, and recorded in up to 480p resolution with a frame rate of thirty frames per second at maximum (Sullivan et al, 2021). At times, children would protest wearing the head-camera; in these cases, the device was carried from location to location and placed close to the infant (Sullivan et al, 2021). Head-camera videos were filmed naturalistically twice a week, at one set and one random time, with recording periods continued for ninety minutes or until the camera ran out of battery (Sullivan et al, 2021). In all, more than 1,008 video clips were recorded, totalling over five hundred hours of audio-visual data (Sullivan et al, 2021).

Videos were examined with iMotions' facial expression analysis software (version 9.3), using the Affectiva AFFDEX software development kit (SDK, version 5.1). AFFDEX incorporates an algorithm trained on a database of over 100,000 faces, thus can identify where faces and facial features occur, detect facial muscle movement, and categorise emotional facial expressions (McDuff et al, 2016). The software functions by fitting a 'face box' containing landmarks for the eyes, nose, and chin to each detected face (McDuff et al, 2016). AFFDEX then categorises facial expressions into various emotion categories, namely neutral, anger, contempt, disgust, fear, joy, sadness, surprise, confusion, and sentimentality

(McDuff et al, 2016). A ‘probability value’ ranging from 0, indicating the emotion is likely absent, to 100, indicating the emotion is likely present, is then returned for each emotion category (McDuff et al, 2016). The software also provides measures of engagement and attention, which assess how emotionally engaged and attentive a face is, along with a measure of expression valence (iMotions, 2017). The AFFDEX software has been validated for use in classifying emotional facial expressions from photos and videos (Stöckli et al, 2018, Dupré et al, 2020, Yang et al, 2020), and shows high correlations with classification of emotional facial expressions using facial electromyography (Kulke et al, 2020). In this study, only the six ‘basic’ emotions (anger, disgust, fear, happiness, sadness, surprise) were considered.

Coding

Four independent coders coded the videos. Videos were divided evenly and randomly between coders, so that no individual coded all videos from one infant or all videos from a particular infant age range.

Coders independently viewed the videos in iMotions’ to pinpoint where faces were identified by the software. When a face was identified, it was coded for the person’s gender and identity (i.e., ‘mum’, ‘dad’, ‘other adult female’, ‘other adult male’, ‘other child’). Occasionally, iMotions registered fleeting ‘faces’ where none existed. These instances were closely inspected, and were not coded once it was confirmed the software had returned a false alarm. Faces were also not coded if they were detected but were not within the infant’s field of view or facing the infant, or if the facial landmarks did not match correctly with the corresponding facial features (e.g., the nose erroneously marked as an eye).

Procedure

Data were accessed from the SAYCam data corpus as supplied by Databrary (Sullivan et al, 2017). Videos were downloaded to a single hard drive storage unit, then uploaded to iMotions and coded in batches. Once each batch had been coded, videos were returned to the hard drive, and a new batch was loaded into iMotions. Coding was terminated only when time constraints prevented its continuation.

Once coding was terminated, the data was cleaned and compiled into a csv file. Variables not relevant to the current study were removed from the dataset, and the csv file was configured into an appropriate format for analysis. Statistical analyses were then run to assess the study hypotheses.

Data Analysis

From the compiled data, any frames for which iMotions returned a probability value of ≥ 25% for the 'neutral' emotion category were removed. Detection of a 'neutral' facial expression signified a lack of emotion being expressed, hence could not be considered an *emotional* facial expression.

Emotional facial expression intensity was assessed utilising the probability values iMotions returned for the six basic emotions. As the AFFDEX software categorises expressions based on how well the algorithm recognises them (i.e., how prototypical an expression is), more intense emotional facial expressions are easier for iMotions to recognise. Therefore, a higher probability value signifies a more intense emotional facial expression (Affectiva, 2017).

Emotional facial expression complexity was also assessed using iMotions' returned probability values for the six basic emotions. In the present study, complex expressions are conceptualised as 'compound' emotional facial expressions; those in which the expressions associated with the six basic emotions are mixed to create multi-faceted facial expressions

(LaPlante et al, 2000, Du et al, 2014, Du & Martinez, 2015). Resultantly, simpler expressions should cause iMotions to detect emotions in a smaller number of emotion categories for a single expression. Conversely, more complex expressions should result in expression detection in a larger number of emotion categories. To calculate ‘complexity values’, the number of emotion categories reaching a probability value of ≥ 25% for each frame in which a face appeared was totalled. This cut-off was chosen in line with the minimum thresholds selected in studies investigating expression intensity in emotional facial expression recognition (see Herba et al, 2006, Law Smith et al, 2010). From here, any frames with a complexity value of zero were removed to ensure only valid data was analysed.

Data was analysed using linear mixed effects models via the Jamovi statistical analysis software (The Jamovi Project, version 2.3.13) with the GAMLj package (Gallucci, 2019). Mixed effects models were used here due to non-independence of data points (i.e., multiple measurements from the same individuals). As per the default settings in Jamovi, the restricted maximum likelihood method (REML) was used to fit the model’s fixed effects, and the Satterthwaite method to calculate degrees of freedom. The variables available to be entered into the models included probability value (assessing expression intensity), complexity value (assessing expression complexity), emotion category (for expression intensity analyses only), video ID (i.e., session name), child disability, and child age (in months). The model best fitting the data for each analysis was chosen using the Akaike Information Criterion (AIC) value, where a smaller AIC indicates better model fit. All possible combinations of main and interaction effects were attempted to find the best fitting model for each analysis. When significant interaction effects appeared, they were followed up using Bonferroni-corrected post-hoc tests or with simple effects analyses where appropriate.

Results

Total Data

Due to time constraints, the entire dataset could not be coded. Therefore, as each video contained many instances where faces appeared, coders aimed for feasibility over power and coded as many videos as possible. A total of 791 videos, or 279.06 hours of footage, were coded. Of this, 130.66 hours of data from [redacted], 79.16 from [redacted], and 69.24 from [redacted] were viewed and coded, resulting in 569,884 total coded video frames. After removal of any data frames that could not be analysed (see Methods), the final dataset available for analysis here is summarised in Table 1.

Table 1

Total usable frames for each code for each child

Child	*Mum*	*Dad*	*Adult Female*	*Adult Male*	*Child*
[redacted]	39494	125	823	7	4
[redacted]	40468	783	0	0	17
[redacted]	21207	26386	1896	2532	306

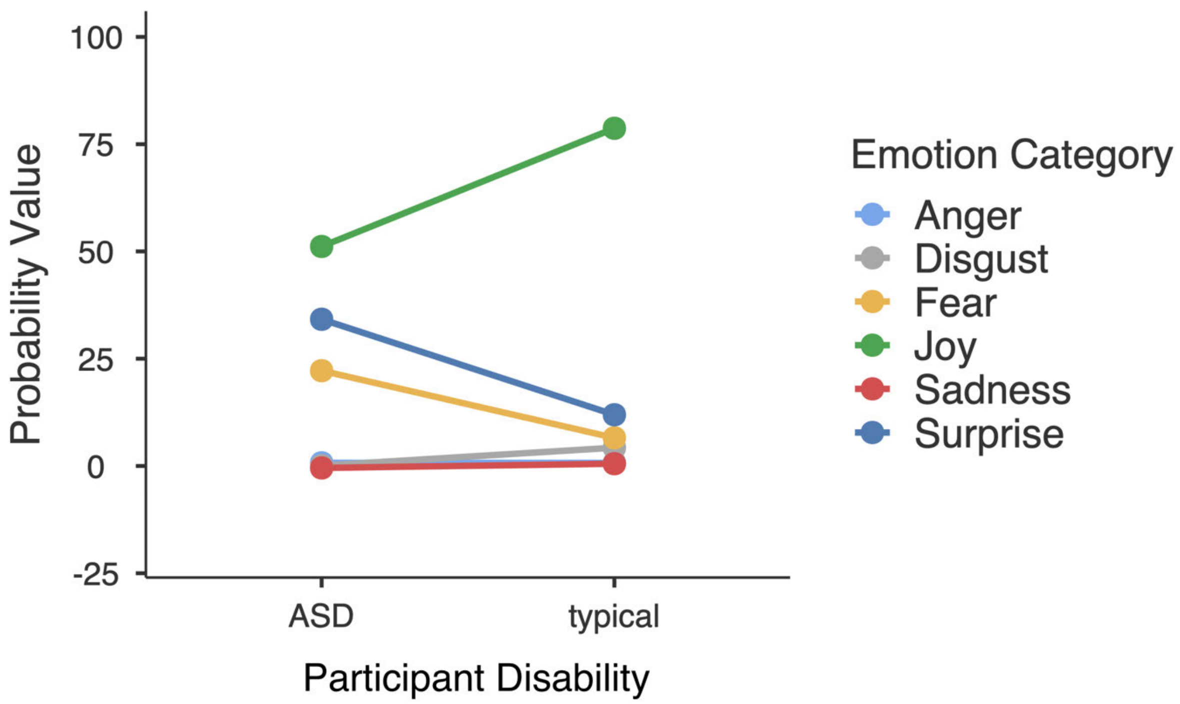
Emotional Facial Expression Intensity

Figure 1 shows the overall intensities for the emotional facial expressions of each emotion category as communicated to the autistic and typically developing children.

To begin the analyses, the influence of the child's later diagnostic status on their interaction partner's emotional facial expression intensity overall was assessed. The following variables were entered into the first linear mixed effects model: probability value, emotion category (anger, disgust, fear, joy, sadness, surprise), participant disability (ASD, typical), and video ID. The best fitting model (AIC = 742866, R_M^2 = NaN, R_C^2 = NaN) had the formula Probability Value ~ 1 + Emotion Category + Participant Disability + Emotion Category:Participant Disability + (1 | Video ID). Emotion category, participant disability, and an emotion category by participant disability interaction were included as fixed effects, with video ID entered as a random effect. This model found significant main effects of emotion category (F(5, 803750) = 117214.41, p < .001) and participant disability (F(1, 490) = 9.77, p = .002). The interaction between emotion category and participant disability was also significant (F(5, 803750) = 14243.66, p < .001). For the current model, however, R^2 values could not be computed. This indicates although the predictors of emotion category, participant disability, and video ID were significant, they left a large portion of the variance in emotional facial expression intensity unexplained.

Figure 1

Overall intensity of each emotional facial expression category expressed to autistic and typically developing children



The significant participant disability by emotion category interaction indicated the main effect of participant disability may be driven by intensification of certain emotion categories compared to others. Therefore, this effect was investigated further using post-hoc comparison tests with Bonferroni-corrected p-values, the results of which are displayed in Table 2.

Table 2

Results of post-hoc tests comparing the intensity of each emotion category between the autistic and typically developing children

Comparison					
Disability	*Emotion Category*	*Difference*	*SE*	*Z*	*p (Bonferroni)*
ASD - Typical	Anger*	0.01	0.31	0.45	1.00
	Anger**	-0.02	0.32	-0.05	1.00
ASD - Typical	Disgust*	-4.17	0.31	-13.50	< .001
	Disgust**	-4.27	0.32	-13.41	< .001
ASD - Typical	Fear*	15.65	0.31	50.72	< .001
	Fear**	15.88	0.32	49.88	< .001
ASD - Typical	Joy*	-27.55	0.31	-89.25	< .001
	Joy**	-28.02	0.32	-88.02	< .001
ASD - Typical	Sadness*	-0.99	0.31	-3.20	.091
	Sadness**	-1.01	0.32	-3.17	.1
ASD - Typical	Surprise*	22.25	0.31	72.11	< .001
	Surprise**	22.48	0.32	70.63	< .001

Note. * signifies the estimate without age entered into the model. ** signifies the estimate with age entered as a covariate and fixed effect.

Visible from Table 2, overall expressions of joy and disgust communicated to the typically developing children, [redacted] and [redacted], were significantly more intense than those conveyed to the autistic child, [redacted]. Conversely, the expressions of fear and surprise displayed to the autistic child were significantly more intense than those seen by the typically developing children. However, there were no significant differences in the overall intensity of angry and sad emotional facial expressions communicated to either group of children.

Secondly, the influence of the child's later diagnostic status and age on their interaction partner's emotional facial expression intensity over time was investigated. Figures 2 and 3 shows changes in intensity for the emotional facial expressions of each category as communicated to the autistic and typically developing children.

Figure 2

Intensity of each emotional facial expression category expressed to the autistic child over time with age (no scaling)

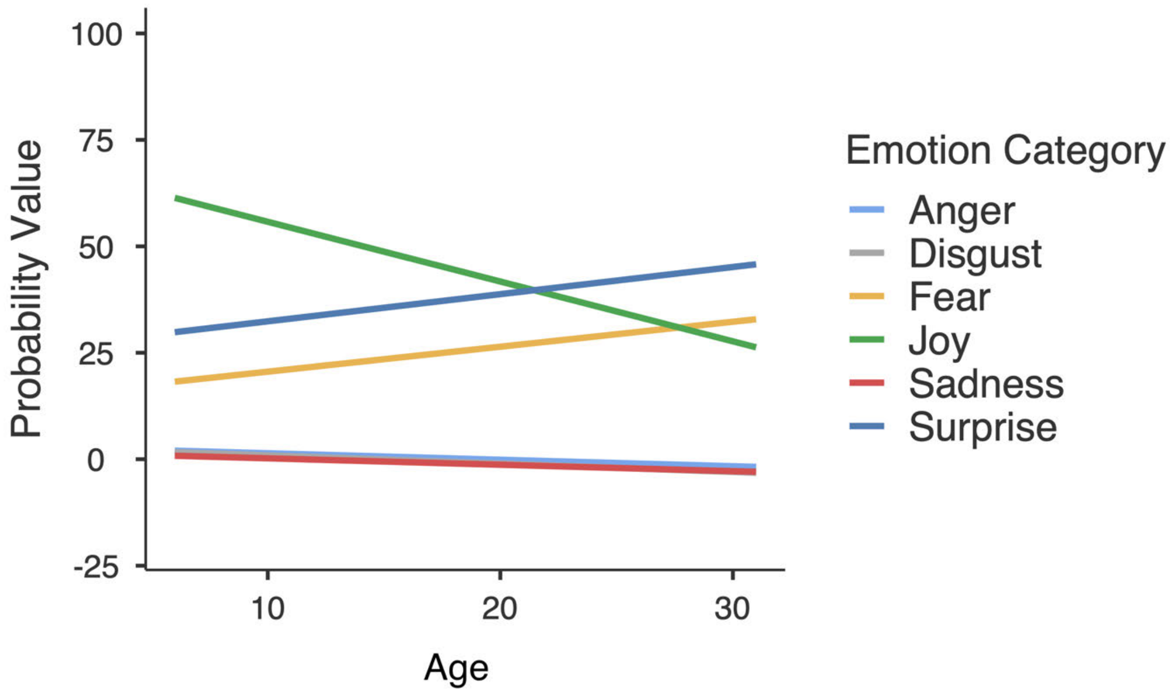
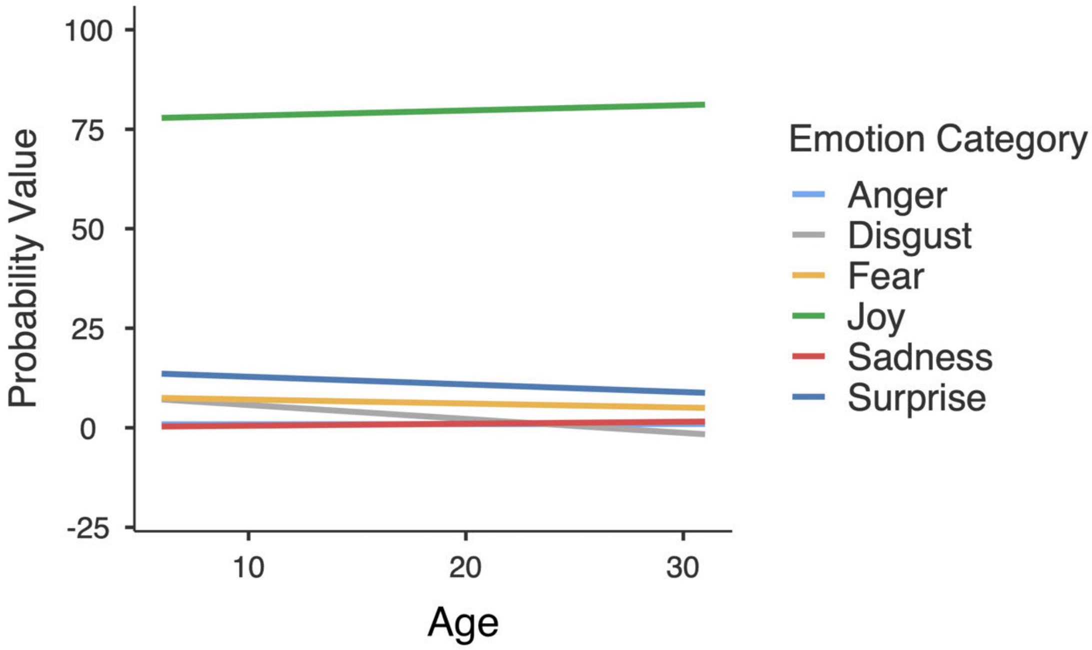


Figure 3

Intensity of each emotional facial expression category expressed to the typically developing children over time (no scaling)



The following variables were entered into a second linear mixed effects model: probability value, emotion category (anger, disgust, fear, joy, sadness, surprise), participant disability (ASD, typical), video ID, and child age. The best fitting model (AIC = 7424415, R_M^2 = NaN, R_C^2 = NaN) had the formula Probability Value ~ 1 + Participant Disability + Emotion Category + Age + Participant Disability:Emotion Category + Age:Participant Disability + Age:Emotion Category + Age:Emotion Category:Participant Disability + (1 | Video). Here, emotion category, participant disability, and four interactions including disability by emotion category, age by emotion category, age by disability, and age by emotion category by disability were entered as fixed effects. Age was entered as a covariate and fixed effect, plus video ID as a random effect.

This model found significant main effects of participant disability ($F(1, 454) = 8.469$, $p = .004$), emotion category ($F(5, 803738) = 116375.936$, $p < .001$), and age ($F(1, 525) = 14.033$, $p < .001$). The disability by emotion category interaction was also significant (F(5, 803738) = 14666.590, $p < .001$), as was the emotion category by age interaction ($F(5, 803738) = 446.323$, $p < .001$). Though the participant disability by age interaction was non-significant ($F(1, 525) = 0.538$, $p < .464$), the participant disability by emotion category by age interaction was significant ($F(5, 803738) = 742.883$, $p < .001$). Again, R^2 values could not be computed, indicating emotion category, participant disability and age, plus video ID left a large portion of the variance in expression intensity unexplained.

To further investigate the disability by emotion category interaction, this time with age included in the model, post-hoc comparison tests with Bonferroni corrected alphas were performed. The results of these tests are displayed in Table 2, which showed the patterns observed without age in the model remained. However, once age was entered, the intensity differences for sad expressions became significant, such that the typically developing children saw more intense sad expressions over time.

Furthermore, considering the significance of the other interactions included in the model, these effects were further analysed using simple effects analyses. These results are shown in Table 3.

Table 3

Results of simple effects comparing the effects of age, disability, and emotion category on changes in expression intensity per month between the autistic and typically developing children

Moderator Levels						
Emotion Category	*Disability*	*Estimate*	*SE*	*95% CIs*	*Z*	*p*
Anger	ASD	-0.15	0.05	[-0.25, -0.06]	-3.15	.002
	Typical	0.004	0.03	[-0.06, 0.07]	0.12	.902
Disgust	ASD	-0.19	0.05	[-2.88, -0.10]	-4.02	<.001
	Typical	-0.35	0.03	[-0.41, -0.29]	-10.97	<.001
Fear	ASD	0.59	0.05	[0.49, 0.68]	12.16	<.001
	Typical	-0.10	0.03	[-0.16, -0.04]	-3.13	.002
Joy	ASD	-1.40	0.05	[-1.50, -1.31]	-29.12	<.001
	Typical	0.13	0.03	[0.07, 0.20]	4.174	<.001
Sadness	ASD	-0.15	0.05	[-0.25, -0.06]	-3.13	.002
	Typical	0.05	0.03	[-0.01, 0.11]	1.55	.120
Surprise	ASD	0.64	0.05	[0.54, 0.73]	13.23	<.001
	Typical	-0.19	0.03	[-0.25, -0.13]	-6.02	<.001

Illustrated in Table 3, the intensity of the angry, joyful, and sad emotional facial expressions communicated to the autistic child, [redacted], decreased over time. This decrease was particularly pronounced for joy, which saw the largest change in intensity for any emotion across all children. Contrastingly, expressions of fear and surprise seen by [redacted] intensified markedly as his age increased, showing the second and third steepest rates of intensity change per month for all children. Conversely, for the typically developing children, the fearful and surprised expressions lessened in their intensity, while the joyful expressions intensified further with increasing child age, though at much slower rates than for [redacted]. For these two children, the intensity of angry and surprised expressions, however, did not change as they grew older. Finally, for all children, the intensity of disgusted emotional facial expressions lowered over time.

The estimated parameters for the fixed effects of both models assessing emotional facial expression intensity (overall and with child age) are displayed in Table 4.

Table 4

Results of LMMs investigating emotional facial expression intensity

Effect	*Estimate*	*SE*	*95% CIs*	*Test (df)*	*p*
Intercept*	17.55	0.14	[17.28, 17.82]	t = 126.02 (490)	< .001
Intercept**	17.72	0.14	[17.44, 18.00]	t = 122.54 (454)	< .001
Disgust – Anger*	1.46	0.10	[1.25, 1.66]	t = 14.12 (803750)	< .001
Disgust – Anger**	1.48	0.10	[1.27, 1.68]	t = 14.324 (803738)	< .001
Fear – Anger*	13.66	0.10	[13.46, 13.86]	t = 132.52 (803750)	< .001
Fear – Anger**	13.80	0.10	[13.60, 14.00]	t = 133.92 (803738)	< .001
Joy – Anger*	64.22	0.10	[64.02, 64.42]	t = 623.12 (803750)	< .001
Joy – Anger**	63.98	0.10	[63.78, 64.18]	t = 620.790 (803738)	< .001
Sadness – Anger*	-0.68	0.10	[-0.89, -0.48]	t = -6.63 (803750)	< .001
Sadness – Anger**	-0.69	0.10	[-0.89, -0.48]	t = -6.66 (803738)	< .001
Surprise – Anger*	22.34	0.10	[22.14, 22.55]	t = 216.79 (803750)	< .001
Surprise – Anger**	22.50	0.10	[22.30, 22.70]	t = 218.36 (803738)	< .001
typical – ASD*	-0.87	0.28	[-1.42, -0.33]	t = -3.13 (490)	.002
typical – ASD**	-0.84	0.29	[-1.40, -0.27]	t = -2.91 (454)	.004
Age**	-0.09	0.02	[-0.14, -0.04]	t = -3.72 (490)	< .001

Note. * signifies the estimate without age entered as a covariate and fixed effect. ** signifies the estimate with age entered as a covariate and fixed effect.

Table 4 shows joy was the most intense expression shown to all children, followed by surprise, fear, disgust, anger, and sadness. Confirming previous analyses, Table 4 also illustrates significantly more intense emotional facial expressions were communicated to the autistic child compared to the typically developing children. Also confirmatory, the intensity of facial expressions conveyed to all children generally decreased with age.

The random effects components of both models investigating emotional facial expression intensity (overall and with age) are displayed in Table 5. Visibly, video ID accounted for only a small portion of the variance in expression intensity, while a far larger portion of variance was left unexplained in both models. This suggests though video ID controlled for some of the variance in expression intensity, there remained much additional variance none of the variables included in either model could account for.

Table 5

Random Effects Results of LMM investigating emotional facial expression intensity

	Overall				By Age			
Groups	*Name*	*SD*	*Variance*	*ICC*	*Name*	*SD*	*Variance*	*ICC*
Video	(Intercept)	2.85	8.15	0.013	(Intercept)	2.81	7.91	0.013
Residuals		24.50	600.01			24.43	596.82	

Emotional Facial Expression Complexity

Figure 4 shows the complexities of the emotional facial expressions as communicated to autistic and typically developing children with age.

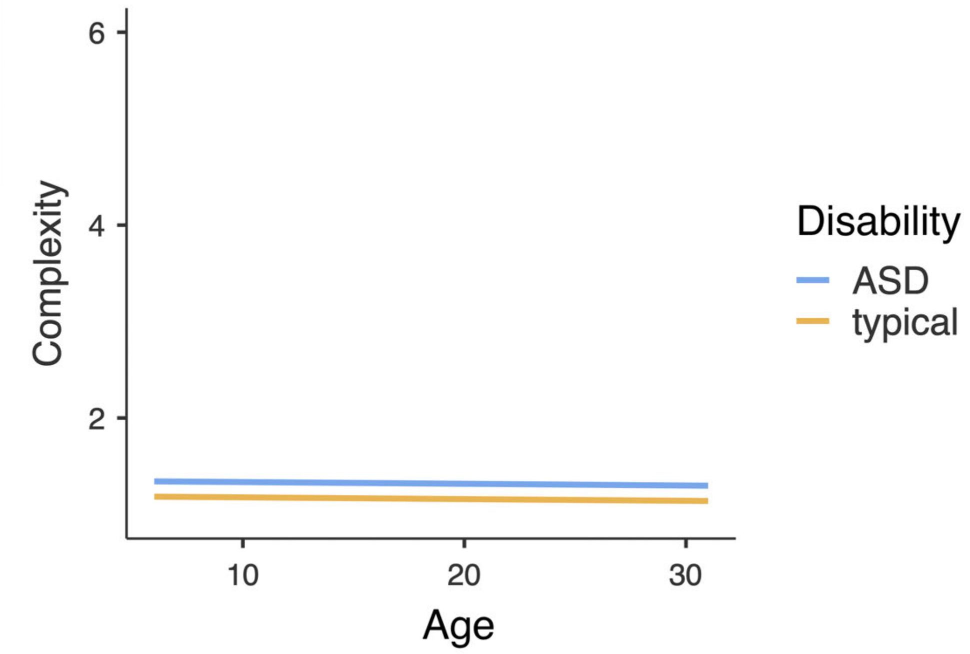
To begin, the influence of the child's later diagnostic status on their interaction partner's overall emotional facial expression complexity was assessed. The following variables were entered into a third linear mixed effects model: complexity value, participant disability (ASD, typical), and video ID. The best fitting model (AIC = 160831, R^2_M = NaN,

R_C^2 = NaN) had the formula Expression Complexity ~ 1 + Participant Disability + (1 | Video ID). Here, participant disability was entered as a fixed effect, and video ID as a random effect. This model found a significant effect of participant disability, $F(1, 526) = 49.2$, $p < .001$. However, as with the analyses of expression intensity, the R^2 values for the current model could not be computed. This signifies participant disability and video ID left a large portion of the variance in expression complexity unexplained.

Subsequently, the effect of the child's later diagnostic status and age on their interaction partner's emotional facial expression complexity over time was investigated. The following variables were entered into a fourth linear mixed effects model: expression complexity, participant disability (ASD, typical), video ID, and child age. The best fitting model (AIC = 160832, R_M^2 = NaN, R_C^2 = NaN) had the formula Expression Complexity ~ 1 + Age + Participant Disability + (1 | Video). Participant disability was entered as a fixed effect, video ID as a random effect, and age as a covariate and fixed effect. This model found a significant main effect of participant disability, $F(1, 525) = 47.661$, $p < .001$, but the main effect of child age was non-significant, $F(1, 525) = 0.823$, $p = .365$. The very subtle differences in AIC values between the two expression complexity models further confirm age had little impact on the complexity of emotional facial expressions seen by all children. Again, R^2 values for the current model could not be computed, indicating participant disability and age, plus video ID left much of the variance in expression complexity unexplained.

Figure 4

Complexity of the emotional facial expressions expressed to the typically developing children with age (no scaling)



The estimated fixed effects parameters of both models assessing emotional facial expression complexity (overall and with child age) are displayed in Table 6.

Table 6

Results of LMMs investigating emotional facial expression complexity

Effect	*Estimate*	*SE*	*95% CIs*	*Test (df)*	*p*
Intercept *	1.25	0.01	[1.22, 1.27]	t = 108.94 (526)	< .001
Intercept **	1.25	0.01	[1.23, 1.27]	t = 102.319 (505)	< .001
Typical – ASD*	-0.16	0.02	[-0.21, -0.12]	t = -7.02 (526)	< .001
Typical – ASD**	-0.16	0.02	[-0.20, -0.11]	t = -6.904 (525)	< .001
Age**	-0.002	0.002	[-0.006, 0.002]	t = -0.907 (525)	.365

Note. * signifies the intercept estimate without age entered as a covariate and fixed effect.
** signifies the intercept estimate with age entered as a covariate and fixed effect.

Confirming the previous findings, Table 6 shows emotional facial expressions communicated to the autistic child were significantly more complex than seen by the typically developing children. Additionally, there appeared no significant changes in expression complexity with child age for any child.

The random effects components of both models investigating emotional facial expression complexity (overall and with age) are displayed in Table 7. Here, video ID accounts for an even smaller portion of the variance in expression complexity than it did for expression intensity, both overall and with age. However, the residuals also explained only a limited portion of the remaining variance. Taken together, these results suggest there was little variation in emotional facial expression complexity between autistic and typically developing children, overall and across the lifespan.

Table 7

Random Effects Results of LMM investigating emotional facial expression complexity

	Overall				By Age			
Groups	*Name*	*SD*	*Variance*	*ICC*	*Name*	*SD*	*Variance*	*ICC*
Video	(Intercept)	0.25	0.06	0.25	(Intercept)	0.25	0.06	0.25
Residuals		0.44	0.19			0.44	0.19	

Discussion

The current study investigated how emotional facial expressions are communicated to autistic and typically developing young children, and how these expressions change with increasing child age. Overall, the hypotheses were partially supported. Consistent with Hypothesis 1a, expressions communicated to the autistic child, [redacted], were more intense overall than those conveyed to the typically developing children. However, a significant interaction effect revealed this finding was driven by more intense surprised and fearful expressions seen by [redacted] overall. Partially consistent with Hypothesis 2a, typically developing children saw emotional facial expressions of all categories but joy decrease in intensity or remain as intense over time. Meanwhile, inconsistent with Hypothesis 3a, the intensity of all expressions conveyed to the autistic child changed over time. [redacted] viewed increasingly intense surprised and fearful, but less intense angry, disgusted, joyful, and sad expressions over time. Finally, opposite to all predictions of expression complexity, more complex emotional facial expressions were conveyed to the autistic child. Additionally, neither group saw changes in expression complexity with increasing age. In all, the interaction between ASD and infant-directed facial expressions appears highly intricate.

These results corroborate our existing knowledge on ASD in children, while also bridging prevailing research gaps by providing a new perspective, the child's own visual experience. Regarding expression intensity, autistic individuals regularly require more exaggerated emotional facial expressions to correctly identify them (Rump et al, 2009, Law Smith et al, 2010, Wong et al, 2012, Song & Hakoda, 2017). These difficulties may be driven, or at least worsened, by the use of more 'rule-based' strategies in ASD when perceiving emotional facial expressions. In these strategies, autistic adolescents and adults learn regularities by which to recognise emotional facial expressions (e.g., a smile means a happy expression)

(Rutherford & McIntosh, 2007, Walsh et al, 2014). They then extrapolate these regularities to mean the more they are exaggerated, the more likely a face is portraying the relevant emotion (e.g., the further the mouth corners are pulled upwards, the happier the expression is) (Rutherford & McIntosh, 2007, Walsh et al, 2014). The current findings suggest such perceptive differences may arise in early childhood, a possibility bolstered by the utility of exaggerated facial expressions in alleviating social orienting or joint attention deficits in ASD. Autistic children as young as six months often preferentially orient towards non-social over social stimuli, exhibit difficulties engaging in joint attention with others, and look less at the faces of their interaction partners (Dawson et al, 1998, Shic et al, 2011, Chawarska et al, 2013, Sasson & Touchstone, 2014, Chita-Tegmark, 2016, Franchini et al, 2017a, 2017b, Vacas et al, 2021). Using intensified emotional facial expressions can better draw these young child's attention towards faces, or increase their responsiveness to unfolding social situations (Chawarska et al, 2013, Franchini et al, 2017a). Therefore, performing such modifications appears an additional cue prompting autistic children to attend to emotional content in social situations.

When investigating emotional facial expression intensity overall, expressions of joy and surprise were the most intense overall for all children. These were followed by the negatively-valenced emotions in varying orders for each child. That joy and surprise were the most intense expressions adheres to the existing literature on the facial expressions shown to young children. Infant-directed facial expressions often portray happy or positively-valenced surprised expressions (Chong et al, 2003, Kim & Johnson, 2013, 2014). Moreover, infants appear particularly attracted to positive affect. Happy expressions are some of the first infants learn to differentiate from others (Herba et al, 2006, Gao & Maurer, 2009, 2010), and their preference for infant-directed facial expressions may be mediated by positive affect (Kim &

Johnson, 2013). For autistic children, meta-analytic evidence has suggested recognition of happy expressions may be some of the least impaired in ASD (Uljarevic & Hamilton, 2013, Lozier et al, 2014). In fact, eye-tracking studies have demonstrated young autistic children show similar looking patterns for happy faces as typically developing children (Vacas et al, 2021). Thus, the current results also support the proposition that a preference for happy faces in early childhood transcends disability status, and hence are elicited from their interaction partners more often.

However, despite being the most salient expressions seen by all children, the joyful expressions communicated to the autistic child were significantly less intense, and their intensity diminished even further with increasing child age. Additionally, the autistic child, [redacted], saw significantly more intense surprised, fearful, and disgusted expressions than the typically developing infants overall. Though all children saw disgusted expressions become more subtle over time, the surprised and fearful expressions conveyed to [redacted] intensified with age, while they lessened in intensity for [redacted] and [redacted]. These changes were prominent to the extent that, as seen in Figure 3, surprised and fearful expressions shown to [redacted] eventually became more intense than any joyful expressions he saw. Though it cannot be definitively determined what caused these intensity differences, potential explanations are posed here. Just like autistic individuals may struggle to understand the motives of typically developing others, typically developing individuals can demonstrate ‘mind-blindness’ towards autistic others. Defined as the inability to interpret and understand the mental state of others, mind-blindness may arise from how the autistic individual moves, expresses themselves, or interacts with others (Sheppard et al, 2015, Edey et al, 2016, Alkhaldi et al, 2019). For autistic individuals, mind-blindness on the part of their typically developing peers often leads to less favourable impressions of them being formed (Sheppard et al, 2015, Edey et al, 2016, Alkhaldi et al, 2019). Though mind-blindness has mainly been investigated in evaluating unfamiliar autistic strangers, the current results suggest it may also be influential when interacting with familiar persons. Due to his disability, [redacted]'s interaction partners may have perceived him less positively, and found it difficult to interpret or predict his responses in social and emotional exchanges. Hence, they may have displayed more surprised or fearful expressions when [redacted] responded contrary to their expectations.

Furthermore, the way in which [redacted] expressed emotionally may have exacerbated these difficulties. Among other non-verbal communication deficits common in ASD, autistic individuals produce emotional facial expressions that more ambiguous and difficult for others to recognise (Brewer et al, 2016, Grossard et al, 2020). They also display these expressions less often and for shorter amounts of time (Trevisan et al, 2018). [redacted]'s interaction partners may have thus had increased difficulty reading his facial expressions, especially in naturalistic environments where other stimuli are competing for their attention. Accordingly, they may have struggled to read or mirror his facial expressions, and found fewer opportunities to reinforce or encourage his emotional expressions by communicating joy. Moreover, as children grow, they become increasingly active participants in social and emotional exchanges. They gain more autonomy, both over their bodies and how they can communicate, and are freer to engage in social situations as they see fit. Therefore, considering symptoms of ASD generally appear early in a child's development (American Psychiatric Association, 2013), ASD-related social-emotional deficits will become more noticeable with increasing age. Therefore, as [redacted] grew more actively involved in social interactions, others likely increasingly struggled to communicate with him. They may have had greater difficulty engaging [redacted]'s attention socially, increasingly shown fearful or surprised expressions when he behaved in unexpected ways, or found fewer and fewer opportunities to reinforce his behaviour by expressing joy.

Compared to the findings for expression intensity, results opposite to those predicted by all complexity hypotheses were found. Considering the lack of research on complexity in infant-directed facial expressions (Kim & Johnson, 2013), there are currently fewer definitive empirical explanations for these effects. However, the potential justifications provided for expression intensity differences may have also come into play here. Infant-directed modifications are usually simpler and less complex than communication used between adults (Brand et al, 2002, 2007, Brand & Shallcross, 2008). Initially, it was hypothesised [redacted]'s interaction partners would make greater use of these simplified emotional facial expressions, avoiding complex and possibly more confusing expressions to facilitate easier emotional communication. However, it appears such an interaction manifests in the opposite direction. Like intensifying one's facial expressions, increasing their complexity is perhaps another key distinguishing feature of infant-directed communication adaptations for autistic children. Considering autistic individuals may not instinctively attend to social stimuli (Dawson et al, 1998, Shic et al, 2011, Chawarska et al, 2013, Vacas et al, 2021), or use information contained in such stimuli in an atypical manner, additional strategies are required to enhance their social experiences. Through blending elements from several emotion categories into single expressions, [redacted] may have become better engaged in these social situations and emotional exchanges. Some investigations have even found for typical adults, complex emotional facial expressions may be more easily recognised than simple expressions, likely due to their increased saliency and attention-grabbing properties (LaPlante & Amabady, 2000). Therefore, considering children with ASD may require additional compensatory strategies to draw their attention to social stimuli, these more complex expressions may have served the purpose of increasing [redacted]'s social engagement and attention.

The 'mind-blindness' hypothesis may also contribute here. As [redacted]'s interaction partners likely experienced increased difficulty communicating emotionally with him, they may have displayed more complex emotional facial expressions like confusion, concern, or caution. Though the Affectiva SDK did include confusion as a detectable emotion category, there exists less theoretical background for assessing confusion as an emotional facial expression than the six basic emotions. Additionally, little information about how confusion was assessed by the software could be identified, thus it was not utilised in the current study based on theoretical grounds.

However, the lack of changes in emotional facial expression complexity with increasing child age remains harder to explain. Whether no differences were identified due to how complex expressions were conceptualised, assessed with iMotions' software, or simply that changes may have been detected with a longer sampling period remains unknown. Otherwise, parents may have naturally formed a specific method of communicating emotional facial expressions early in their child's development, and continued to use this style throughout the recording period. Nonetheless, that overall differences between the complexity of facial expressions shown to autistic and typically developing children were identified is a step forward in the developmental psychology literature.

The current study has several important implications, from directing future research to informing possible interventions for ASD. To the author's knowledge, this is the first study that investigates the emotional facial expressions communicated to autistic versus typically developing children. Furthermore, most research has focused on how autistic individuals perceive and understand their typically developing peers (Edey et al, 2016). Fewer investigations, however, have considered the opposite; how typically developing individuals perceive and interact with autistic others. The findings of this study extend those of similar investigations comparing dyadic interactions between autistic and typical individuals, and confirm when communicating with autistic others, typically developing individuals adapt their behaviours accordingly. Whereas other studies have identified such adaptations as performed by parents in the laboratory (Meirsschaut et al, 2011, Yoshida et al, 2020), the current study confirms such adaptations persist in naturalistic settings and over time, and are shown by multiple interaction partners. Furthermore, the utility of this study extends outside the emotional development literature. The current work contributes to the coding of the original SAYCam dataset, which Sullivan and colleagues (2021) have opened for other researchers to contribute to. Given the dataset's size, identifying where faces of certain individuals appear contributes largely to the general coding scheme and the efficiency of future research in developmental psychology and ASD.

The salience of these behavioural adaptations suggests potential avenues for interventions to strengthen the social experience of autistic children. Autistic persons are often perceived less favourably than typically developing others (Stagg et al, 2014, Sasson et al, 2017, Alkhaldi et al, 2019, DeBrabander et al, 2019), and have been demonstrated here to see less joyful emotional facial expressions. Furthermore, the intensity of these joyful expressions seen by autistic children decreases markedly as the child ages, while it increased for typically developing children. Displays of positive affect, particularly within the home, have significant positive impacts on a child’s emotional knowledge and expression (Halberstadt & Eaton, 2002, Planalp et al, 2016, Ogren & Johnson, 2021). Considering the recognition of happy facial expressions may be relatively unimpaired in ASD (Uljarevic & Hamilton, 2013, Lozier et al, 2014, Vacas et al, 2021), a decrease in the use of positive affect towards children with ASD is likely unnecessarily detrimental for their later emotional development. Interventions should therefore look towards increasing displays of positively-valenced expressions to autistic children, especially within their own homes, to ensure optimal emotional wellbeing can be achieved.

Similarly, those posing interventions targeted at improving the emotional knowledge of autistic children should seek to integrate typically developing others with whom autistic children may interact. Social interactions are a two-way street, hence characteristics of typically developing individuals also majorly contribute to the socio-communicative difficulties seen of ASD (Sasson et al, 2016, DeBrabander et al, 2019, Morrison et al, 2019). Having difficulty interpreting the mental state of autistic individuals, or holding stigmatised beliefs towards ASD as a condition are two major contributors on the part of typically developing individuals in this area. Therefore, typically developing others need to be better informed and more understanding of ASD and its related deficits to promote the social-emotional wellbeing of those diagnosed with the condition. Resultantly, their exclusion from such interventions would only render them less effective for all parties.

Finally, the current thesis points the field towards certain topics requiring further investigation. Determining why autistic children may see more complex emotional facial expressions is a top focus. Considering a rather generalised examination of expression complexity is presented here, and that other investigations have shown complex emotional facial expressions are more difficult for both autistic and typically developing children to recognise correctly (Fridenson-Hayo et al, 2016), there remain significant questions as to from where and why these complexity differences arise. Moreover, the observed complexity differences highlight the need to investigate emotional facial expressions outside of the 'basic' emotions. Psychology's fixation on this subset of expressions likely limits our understanding of facial expressions overall, by portraying a reductionistic view of what we perceive in naturalistic settings. Finally, future investigations should attempt to disentangle the reasons as to why less joyful, and more fearful or surprised, expressions may be communicated to autistic children. Several possible explanations are posed here, but without additional empirical testing, the true cause of these differences cannot be confirmed.

Despite the utility of the current study, it did have its limitations. To begin, several technological weaknesses were at play. The Affectiva software, though validated for use with videos of varying qualities (Dupré et al, 2020), was sometimes inaccurate and unreliable. There occurred numerous instances where even when a face was presented in optimal conditions, Affectiva would misalign the facial landmarks with the individual's facial features, or fail to detect the face entirely. Resultantly, such faces could not be coded, even though they contained valid data. Furthermore, compared to other facial expression recognition software, Affectiva returns notably lower accuracy and true positive rates, and may under- or overpredict the occurrence of certain emotion categories (Dupré et al, 2020, Yang et al, 2020). However, due to licensing and cost barriers, more accurate software could not be obtained. Future research should therefore consider utilising better performing software.

Nonetheless, video- and camera-related weaknesses contributed to these inaccuracies. Video quality was sometimes diminished due to external factors (e.g., low lighting, excessive backlighting behind the head), causing iMotions to fail to detect faces even if they appeared within the infant's view. Considering the naturalistic design of Sullivan and colleagues' (2021) original data collection, however, such variables were unavoidable as not all natural environments provide optimal recording conditions. Furthermore, camera quality issues (e.g., low frame rate or resolution, fish-eye lens occasionally warping faces at the edge of the camera's field of view) occurred, also depleting iMotions' ability to accurately detect faces.

These variables, however, had less of an effect on videos collected from [redacted]’s headcam, which were significantly clearer than those from [redacted] and [redacted]. Considering data collection for [redacted] occurred several years after [redacted]’s and [redacted]'s, it is speculated a newer model of the camera with better specifications was used. Future investigations utilising similar methodologies should attempt to work around these limitations, such as by regularly updating headcams to the latest available models, but without compromising the study's naturalistic design.

Finally, child-related variables posed significant limitations for the current study. With increasing age, children more often refused to wear their headcams, especially in the case of [redacted]. Consequently, a sizeable portion of [redacted]’s videos at later ages were filmed with the headcam placed nearby, often facing [redacted] himself. This resulted in a loss of potential data, as others were likely expressing to the child behind the camera. Most importantly, however, the sample for this study was extremely limited, containing only three children and a sole autistic child. Autism is a spectrum condition, meaning not all autistic individuals will experience the same deficits to the same degree. Though emotion recognition difficulties appear particularly common in ASD, not all autistic individuals experience severe deficits in this area (Loth et al, 2018). Furthermore, all children were from a WEIRD (white, educated, industrialised, rich, democratic; Nielsen et al, 2017) background, and their mothers were all psychology academics. Thus, the generalisability of the results discovered here is significantly diminished. However, as Sullivan and colleagues’ (2021) initial data collection employed a particularly novel design, the current thesis should be considered more an introduction to research in this area. Given the significant effects identified, future research should first focus on completing analyses of the emotional facial expressions within the entire SAYCam dataset. Subsequently, the original methodology should be extended to sample a larger and more diverse range of young children.

In summary, here it is confirmed in a naturalistic, longitudinal setting that emotional facial expressions are communicated differently to autistic and typically developing children, even at very young ages. Autistic children see more complex expressions relative to their typically developing peers. Furthermore, the intensity of joyful, surprised, and fearful expressions seen by autistic and typically developing children appear particularly variable over time. By involving a new perspective, the child's own visual experience, this thesis adds to the literature by providing a more realistic depiction of the emotional facial expressions young children see in their day-to-day life. These findings have several clinical implications, and strongly suggest interventions for ASD should also incorporate those comprising the broader social environment of autistic individuals. Though further research is needed to disentangle some effects, and to work around the identified research limitations, the findings described here are a step forward in the literature.

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