The processing of facial actions in deaf children with autism who use British Sign Language (BSL)

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Resumo

Uma característica chave das crianças com autismo está relacionada com a sua compreensão das outras pessoas e das suas intenções. As crianças com autismo muitas vezes têm dificuldades em interpretar e produzir expressões faciais – de emoção, intenção e comunicação. As línguas de sinais dos surdos requerem o uso fluente de marcadores não manuais (MNMs) na face, e as crianças surdas olham e produzem ações faciais ao se comunicar. A questão colocada neste trabalho é: Como a exigência de observar ações faciais para comunicação, incluindo NMMs, afeta crianças surdas com autismo, em comparação com crianças surdas com desenvolvimento típico? Nos experimentos aqui resumidos, algumas diferenças foram observadas, principalmente em relação à compreensão e produção de expressões relacionadas a estados mentais na língua de sinais. No entanto, outros NMMs, incluindo aqueles considerados linguísticos, foram relativamente preservados em crianças surdas com autismo. Crianças surdas com autismo não são necessariamente prejudicadas na produção ou percepção de muitas ações faciais, sugerindo que a surdez pode atenuar esse aspecto do autismo, devido à necessidade de atenção à face ao se comunicar.

Palavras-chave: transtorno do espectro autista, língua de sinais, ações faciais.

Abstract

A key characteristic of children with autism relates to their understanding of other people and their intentions. They often have difficulties with many aspects of facial processing, including interpreting and producing facial expressions – of emotion, intention, and communication. Sign languages of deaf people require the fluent use of non-manual markers (NMMs) on the face, and deaf children look at and produce facial actions when communicating. The question posed in this work is: How does the requirement to observe facial actions for communication, including NMMs, affect deaf children with autism, compared with deaf children who use a sign language (BSL) but who do not have autism? The experiments summarized here show some differences, with poorer comprehension and production of expressions related to emotions and mental states in sign language for deaf children with autism spectrum disorder (ASD). However, other NMMs involving the face, including some deemed to be linguistic, were relatively preserved in this group. Overall, deaf children with autism were not impaired in the production or perception of many facial actions while using sign language, when compared with deaf children of similar intellectual range and sign language ability. One explanation is that deafness may mitigate this aspect of autism, bestowing better ability with faces due to the requirement to attend to the face when communicating visually.

Keywords: autism spectrum disorder, sign language, facial actions.

Resumen

Los problemas para comprender a otras personas y sus intenciones son una característica definitoria del autismo en niños oyentes. Específicamente, los niños con autismo suelen tener dificultades interpretando y produciendo expresiones faciales que expresan emoción, intenciones y comunicación. Las lenguas de signos usadas por las personas sordas requieren el uso fluido de marcadores no manuales (MNM) en la cara además de que se observen y produzcan gestos faciales durante la comunicación. En este trabajo se planteó la siguiente pregunta: ¿Cómo afecta a los niños sordos con autismo, en comparación con niños sordos con desarrollo típico, el requisito de las lenguas de signos de observar accionas faciales y MNM durante la comunicación? En los experimentos resumidos en este texto se encontraron algunas diferencias entre los grupos. Específicamente, la comprensión y producción de expresiones relacionadas con emociones y estados mentales fue más pobre en niños sordos con autismo que

en niños con desarrollo típico. Sin embargo, oros MNM, incluyendo aquellos que son lingüísticos, estaban relativamente preservados en los niños sordos con autismo.

Palabra clave: trastorno del espectro autista, lenguas de signos, acción facial

Introduction

Sign Languages of Deaf people (SLs) are now accepted as fully-fledged languages, expressed through the modality of visual movement. While the manual components of SLs are considered the major articulators, other body parts play important roles. Non-manual actions (non-manual markers: NMMs) communicate a variety of meanings when deaf people communicate using SL. Facial actions involving the eye region/mouth region (Boyes Breaem & Sutton-Spence, 2001; Dachkovsky & Sandler, 2009), and the disposition of the head and body are implicated (Crasborn, 2006; Mohr, 2014), and can function in various combinations as part of sign language grammar, or to provide affective information during the utterance (Benitez-Quiroz, Gökgöz, Wilbur & Martinez, 2014). Facial actions and facial displays are intrinsic to communicative processing in SL users, and people who use SL, especially deaf people, need to pay particular attention to faces and to facial actions. Proficient SL comprehension is characterized by the receiver's eye gaze focused on the face of the signer (Emmorey, Thompson & Colvin, 2009). SL proficiency requires the communicators to attend to and interpret facial displays and face actions as they occur, along with the stream of manual actions, and deaf people who use a SL show excellent face discrimination and face recognition skills, which can match or exceed those of hearing participants (Bettger, Emmorey, McCullough & Bellugi, 1997; Stoll et al., 2018).

The processing of *facial expressions of emotion* in deaf populations has provided a number of findings. In comparison to hearing children, deaf children may show a delay in efficient categorization of several facial emotions (Hosie et al., 2000; Tsou, Li, Kret, Sabino da Costa & Rieffe, 2020) However, sign language skills in deaf populations may moderate these effects (McCullough, Emmorey & Sereno, 2005)[1]. Emotion terms which can be labelled as such, like ANGRY, WORRIED[2], are signed using facial displays which must be synchronized to the corresponding manual gesture (Goldstein, 2000). These displays correspond to the universal facial actions which are used to indicate mental and emotional states. The content and boundaries of the emotion terms used, however, depend on the culture and language of the community whether that uses speech or sign (Dailey et al., 2010; Russell, 1994). While it has been suggested that deaf signers may categorize facial emotions in ways that differ from the hearing community (Claudino, da Costa, Nascimento & Torro, 2020; Grossman & Kegl, 2007), other studies show that deaf signers do show similar facial expression categorization abilities for both static and dynamic images of the 'universal facial expressions'[3] to those for hearing people who use spoken language (Rodger et al., 2021).

Many *linguistic* functions have been ascribed to facial actions in SLs (Baker & Padden, 1978). The timing, scope and extent of the facial action varies as a function of its role, with different constraints on linguistic facial actions employed as syntactic markers (Pyers & Emmorey, 2008), compared with manual and facial gestures that convey additional non-verbal meaning or affect in the signing of deaf people. Similar facial actions may accompany speech in hearing people (Perniss, Özyürek & Morgan, 2015). SLs allow hands and face to function as co-ordinated action systems for communication. In this respect, they are unlike speech, where one set of articulators is used for spoken language processes. Thus, facial actions can

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[1] The great majority of deaf children are born to hearing parents (Kushalnagar et al., 2010). Consequently, very many deaf children are unable to access a natural language (a SL) from their early caregivers – a necessary component of language development. For this reason, many reports of anomalies in cognitive and linguistic processing in deaf youngsters are based on very heterogenous samples, and SL skills are largely untested (see e.g. Campbell, MacSweeney & Woll, 2014).

[2] Upper case is used to signify an SL term

[3] According to Ekman and colleagues, these are anger, disgust, fear, sadness, surprise, happiness (see Ekman, 1992). This list, and the criteria for universality, are contested. Rodger et al. (2021) provide a useful review of this issue in relation to deafness and sign language.

serve to modify the manual actions with respect to several linguistic functions. Three such actions addressed in this paper are adverbials, negation, and question type (see Figure 1).

Figure 1: Three Linguistic Facial Actions in BSL, posed by native, male BSL users. The first image (left) shows the non-manual adverbial MM. This is a relaxed mouth and head, which may move from side to side, accompanying the manual action-term DRIVE (two hands closed around an imaginary steering wheel). The second image (centre) shows the non-manual sign used for negation (NOT/NOTHING/NO). This requires lateral head movement and a set closed mouth and lowered brow extending over the phrase. The right-most image shows the NMM for a question-type; here shown for WHAT. This uses lowered eyebrows and forward head-tilt, usually produced at the end of the manually signed phrase. Similar head and face actions accompany other Wh-questions (WHY, WHO).

Adverbials: Actions of the lower face, for example the 'TH' face in American Sign Language, where a loose tongue protrusion with a relaxed head, implies 'careless' or 'loosely' when produced synchronously with the manual term (e.g. DRIVE, WALK or WRITE). The facial action modifies the manner of the verb produced manually (Lewin & Schembri, 2009; Liddell, 1980; Woll, 2001), while the spread or duration of the facial action, as well as its variability, can depend on sign order or the characteristics of a particular SL (Lewin & Schembri, 2009).

Negation: In many SLs, including BSL, signalling NOT requires a particular head lateral shake and a specific facial display (straight brows and set, closed mouth) as the primary negation signal (Atkinson, Campbell, Marshall, Thacker & Woll, 2004; Quer, 2012), (see Figure 1).

Question Type YES-NO or closed questions in most SLs require an eyebrow raise, with widened eyes, and a forward head tilt. These actions are aligned with the (manual) proposition being questioned (Dachkovsky & Sandler, 2009). WH- or open questions, by contrast, show with lowered eyebrows, also with a forward head tilt. This facial action usually accompanies the last manual item signed (see Figure 1).

For questions and negation, NMMs – especially of the upper face - may be analogous to the (suprasegmental) intonational aspects of spoken language (Dachkovsky & Sandler, 2009).

While linguistic facial actions are SL-specific, facial actions conveying emotions and mental states carry similar meanings independently of language and language modality; they can be culture-universal or culture specific and occur in both speakers and signers. In speech and in sign, such expressions are not a requirement for a well-formed linguistic utterance at the level of linguistic structure (Elliott & Jacobs, 2013). They accompany the language utterance, signalling the emotional and or intentional state of the communicator in relation to the events communicated. In the case of sign language, they can support descriptions about how others are feeling, or accompany manual signs that label emotions.

In hearing people with autistic spectrum disorder (ASD), a key feature of the condition is a pronounced difficulty in understanding other peoples' actions as a function of their intentional and/or emotional state. Many studies attest to this difficulty when people with ASD are required to process facial displays and actions (see Wieckowski, Flynn, Richey, Gracanin & White, 2020; Yeung, 2022), including recognition of unfamiliar faces in naturalistic conditions (Gehdu, Gray & Cook, 2022; Stantić, Ichijo, Catmur & Bird, 2022). Face processing impairments are found in both adults and children with ASD relative to age-matched peers. Autism is often diagnosed in childhood (van't Hof et al., 2021) and difficulties with face processing are found in children with ASD compared with typically developing children (Annaz, Karmiloff-Smith Johnson, & Thomas, 2009; Sasson, 2006). Processing facial expressions of emotions can be differentially impaired in ASD. In particular, while there can be reasonably accurate classification of (simple, 'canonical') emotional facial expressions such as 'happy', 'sad', 'angry' in people with ASD (Castelli, 2005), more complex displays, especially those which convey specific events involving mentalizing or interacting with others – such as 'puzzled', 'mischievous', and even 'surprise', may be more affected in people with ASD than in controls, reflecting difficulties in understanding how the mental states of others may manifest ('theory of mind' or 'mentalizing') and affect communication (Baron-Cohen, Spitz & Cross, 1993; Yeung, 2022). Moreover, where naturalistic displays of facial emotion are used – with video clips rather than face photographs as the stimulus material – somewhat different patterns can emerge, suggesting there may be different mechanisms for processing dynamic facial actions conveying emotions in people with ASD than in typical development (Keating, Fraser, Sowden & Cook, 2022). ASD difficulties with the processing of emotions may also be affected to a greater extent in production than in comprehension (Keating & Cook, 2020). People with autism may need longer to process facial emotions than typically developing controls (Nagy, Prentice & Wakeling, 2021), and duration of attention to a facial display of a negative emotion may also be affected by ASD (Zhao, Zhang, Fu & Maes, 2016). In hearing people with autism who use spoken language, syntax and lexical processes can be intact. However, there can be anomalous processing of spoken intonation (Hubbard & Trauner, 2007), which affects prosodic processing (Asghari, Farashi, Bashirian & Jenabi, 2021).

These findings lead to interesting questions concerning how deaf signers with autism process faces. On the one hand, they may, like hearing people with autism, show problems in attending to, and processing, faces and facial actions of any sort, reflecting a profound difficulty in understanding facial actions conveying emotional, mental, and especially intentional, states in other people. On the other hand, they may, like typically developing deaf signers, show good face processing skills due to the requirement to observe and use facial actions in SL. These oppositional hypotheses were used to drive the experiments reported here.

The empirical questions posed by this work are: how may ASD affect the comprehension and production of facial actions in BSL? Do linguistic facial actions and emotional actions produced in BSL distinguish deaf children with ASD from their typically developing counterparts? In this overview, we report the main findings from a PhD thesis (Denmark, 2011), parts of which have been published, while others are in preparation for publication (Denmark & Atkinson, 2015; Denmark, Atkinson, Campbell & Swettenham, 2014, 2019). The report is in four sections. All the studies were performed with a group of deaf children with ASD compared with a matched deaf control group. The first section describes participant selection, followed by findings of performance on a test of face processing for identity. The second part reports performance for novel tests for identifying and producing facial expressions. The third part reports the results of tests of imitation of both linguistic and affective facial expressions, and briefly summarizes results for the perception and production of face actions for three specific linguistic processes: adverbials, negation and question-type, using new tests. Finally we discuss the findings in relation to the question 'how do deaf children with ASD, and who use a sign language, process faces and facial actions?'

Part 1 Participants and Test of Face image recognition

Participants: The first task was to identify a group of deaf children and young people with ASD and to match them to a group of deaf children and young people who did not have ASD. These participants were mainly recruited from schools in Southern England, and all used British Sign Language as their main form of communication within their bilingual school programme. A core population of 25 (13 ASD) was identified for these studies. Their ages ranged from 8 years to 18 years. One child in the ASD sample and one deaf child in the control sample had deaf parents who used BSL. ASD in deaf children had been assessed by health and social care professionals via national deaf services, and had received a confirmed medical diagnosis of autism. A social responsiveness scale (SRS; Constantino & Gruber, 2005) was administered as a screening measure to affirm the diagnosis.

Each child with ASD was paired with a typically developing deaf child control matched for age and for nonverbal intellectual ability (Raven's progressive matrices). Because several children with ASD had low language and/or Raven's scores, some of the matched control group were selected to have similar scores, leading to a generally lower level of intellectual and language ability than might be anticipated in a typical deaf cohort.[4] All children satisfied the criterion of severe or profound deafness, with hearing loss of at least 70db in the better ear. Receptive and productive measures of BSL (Herman et al., 2004; Herman, Holmes & Woll, 1999) were administered and were matched for each group. SRS scores distinguished the autistic and non-autistic groups statistically (t-test, $t(23)=6.344$, $p<0.001$), and this was the only measure to do so.

Further details of participants, including their hearing and language status, as well as test development and recruitment procedures, are described elsewhere (Denmark, 2011; Denmark & Atkinson, 2015; Denmark et al., 2014, 2019).

Benton Face Recognition Test

To start, it is important to explore how deaf children with ASD perform on basic perceptual processing of face images before moving to more complex face processing abilities, and especially dynamic facial processing as part of understanding sign language. If a perceptual

[4] The mean percentile scores for the ASD group and the control group on the Ravens test were comparable at less than 30%. A mean percentile of 50% would be expected for a typically developing group, whether hearing or deaf (see e.g. Weichbold & Herka, 2003).

test of face image processing showed differential impairment for ASD that would need to be accounted for in any further explorations.

The Benton facial recognition test (BFRT: Benton, Hamsher, Varney & Spreen,1983; Benton, Sivan, Hamsher, Varney & Spreen,1994) requires the respondent to recognize the correct match - or matches - from among six monotone photographs of people of similar appearance to a target facial image. The correct match differs from the target face in terms of lighting and viewpoint, so the recognition of a specific facial identity cannot be made on the basis of local image characteristics, but requires efficient analysis of the face as a whole – as a configural representation. It is a test which is highly sensitive to neurologically-based disorders of face processing (Duchaine & Nakayama, 2006; Duchaine & Weidenfeld, 2003). BFRT impairments have been reported in ASD in studies with hearing adults and children (Altschuler et al., 2021; Dimitriou, Leonard, Karmiloff-Smith, Johnson & Thomas, 2015; Zagury-Orly, Kroeck, Soussand & Cohen, 2022). Moreover, in people with an ASD diagnosis, face recognition and perception skills have been found to correlate with their social interaction abilities - which is not the case for typically developing controls, whether children or adults (Altschuler et al., 2021; Corbett, Newsom, Key, Qualls & Edmiston, 2014).

For deaf people, some studies report that they can be better at facial identification tasks than hearing people (Bettger et al., 1997; Megreya & Bindemann, 2017), but this is not always the case (Stoll et al., 2018). Exposure to and use of SL can be a major contributory factor for face processing skills when deaf people are compared with hearing non-signers (Caselli, Occhino, Artacho, Savakis & Dye, 2022; McCullough & Emmorey, 1997; Stoll et al., 2018). The evidence points towards the use of sign language rather than deafness *per se,* as an enhancing factor in face processing.

Children were tested individually, using the long-form version of the BFRT (54 items) presented in booklet form, and the standard testing procedure. Instructions were translated into

BSL by the experimenter, and responses made by pointing to the correct match(es). t-tests comparing the two groups showed no significant difference ($t(23) = .164$, $p > .05$).The mean score for the typically developing group was 42.9 (SD=5.7). For the ASD group it was 39.3 (SD= 6.3).

Further analyses tested whether the rankings of performance on the BFRT, using aged-based standardized norms for hearing people, distinguished the groups. The deaf ASD group had five participants with normal scores, three borderline and five with severe impairments. In the deaf control group six participants had normal scores, three had borderline scores, two were moderately impaired and one participant was severely impaired. Thus, the groups did not appear to differ greatly in how the face scores were distributed, although it should be noted that there were five who were severely impaired in the ASD group, compared with one in the control group. An analysis splitting the ASD group into a high functioning (n=7) and a low-functioning (n=6) group failed to find any significant difference on BFRT (Denmark, 2011).

Thus, when tested on a standardized test of facial recognition which has been shown to be sensitive to ASD in hearing populations, these deaf children and young people, well matched for age, nonverbal intellect and BSL skills, showed no significant difference as a function of autism. While we cannot rule out that larger numbers of studies on hearing children may have found some group differences, we can infer that, for deaf children and young people who use BSL, those with ASD show similar face recognition skills to a well matched deaf control group with a similar range of intellectual and signing abilities.

Part 2 Emotional Expression in Facial Actions

a) Does ASD affect the comprehension of facial expressions of emotion? In the first experimental study reported here we explored the classification and production of facial expressions of emotion as they are used in BSL by the deaf children in the two groups. This study followed the method pioneered by Reilly in exploring the acquisition of facial emotion processing skills in children (Reilly, McIntyre & Seaga, 1992; Reilly, McIntyre & Bellugi, 1990). Videoclips of a native deaf signer who produced 11 neutral-content statements in BSL were presented to subjects one clip at a time. Different versions of each statement showed different emotional facial expressions. For example, the signed utterance: FRIEND POINT FOUND DOG WANDER ('My friend found her dog wandering'), when signed manually could be delivered with an 'angry' or a 'disgust' facial expression as well as a 'neutral' face.

Respondents were asked to classify the emotion that they believed the signer was producing from a set of eight possible labelled choices on a printed sheet. The expressions used by the signing model, in addition to 'neutral' face, were 'happy', 'sad', 'angry', 'disgust' 'surprised', 'annoyed', and 'mischief'. The first five expressions are usually considered universal (along with 'fear', see Ekman & Oster, 1978). However, among these, 'surprise', as well as 'mischief' and 'annoyed' may signal more complex mental states whose interpretation may depend more on abilities to interpret the mental states of others. We predicted that these particular expressions may cause additional difficulty for the ASD group (Widen & Russell, 2010). A further manipulation condition (also following Reilly's method) was designed to inform the extent to which the face of the signer was processed. In this condition, the face of the signer was digitally masked, since it was possible that the manual display alone could carry emotional information in terms of rate of manual action, body pose and other non-facial cues. Masked and unmasked conditions were mixed in the experiment, which comprised 24 trials showing the eight different emotions. Further details can be found in Denmark et al. (2014).

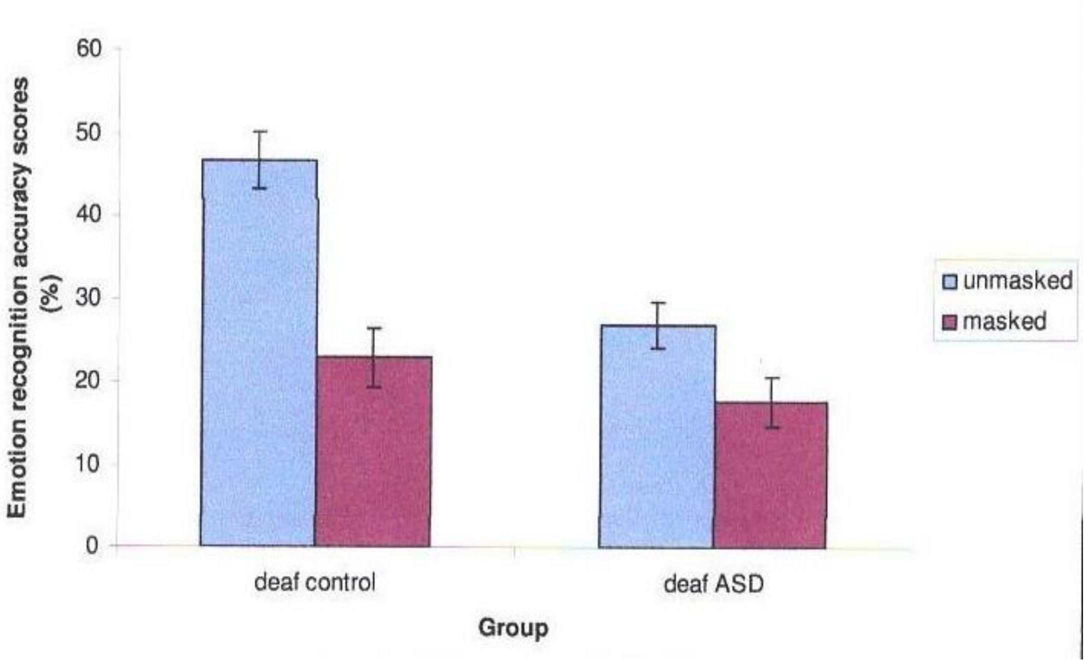


Figure 2: Emotion recognition in BSL with digitally masked and unmasked facial expressions. This shows poorer emotion recognition (around 25% mean accuracy) in the experimental group of deaf youngsters with ASD compared with deaf controls (mean accuracy around 35%). The difference was more marked for the unmasked condition (light blue) than when the face was masked (maroon). That is, the experimental participants were both poorer at identifying the expression and were less affected by masking the face than their controls (Denmark et al, 2014).

The overall results are summarized in Figure 2, which shows that while masking affected control group accuracy, it had less effect on the group with ASD, which performed less accurately than controls in the unmasked condition across the emotions.

Further analyses showed that accuracy for 'simple' (happy, sad, neutral, and angry) unmasked emotions differed significantly, with ASD performing worse than controls. Thus, children and young deaf people with ASD may make less use of facial information in appraising emotional expressions (face masking did not significantly affect accuracy) than their typically developing deaf counterparts of matched sign language ability and of similar intellectual range. Unlike identity recognition of unfamiliar face photographs, which appeared relatively unaffected by ASD in this population, emotional facial expression categorization of dynamic faces was impacted by ASD, in line with reports for hearing children and young people with ASD.

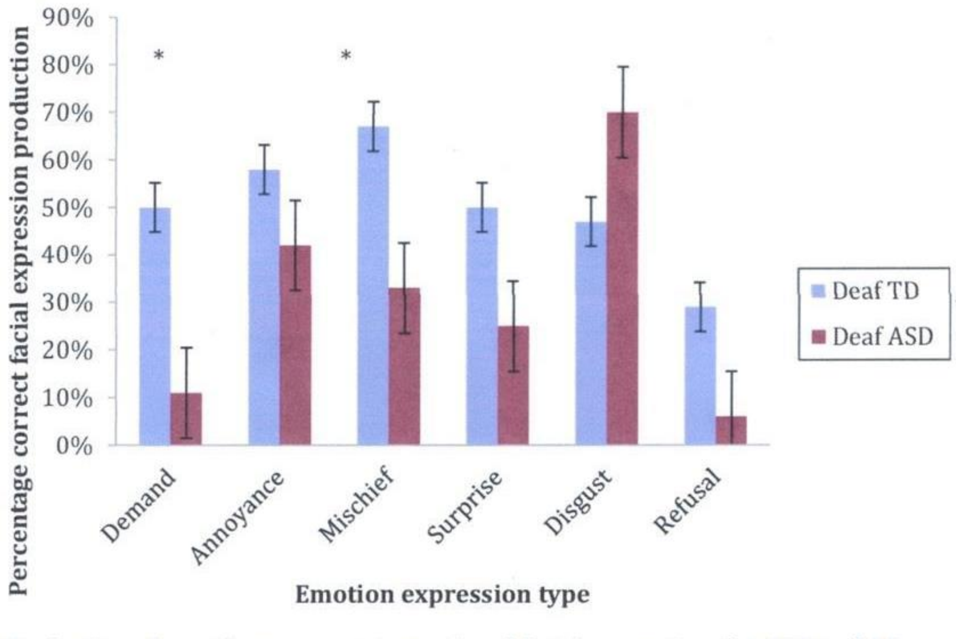
Further analyses explored whether specific facial expressions (in the unmasked condition) showed significant differences as a function of group membership. ‘happy’ ‘angry’ and ‘mischief’ were all recognized less accurately in the ASD group. Of these, ‘mischief’ is likely to have required mentalizing skills.

b) Does ASD affect the production of facial expressions? The perception of emotional facial action during sign language processing was affected by ASD in this sample of young deaf signers, but what about their production? The production of emotional facial expressions in hearing people with ASD can differ both in quantity and quality from that for neurotypical people, with reports of fewer and less appropriate face actions than in typically developing people (Trevisan, Hoskyn & Birmingham, 2018). In the study reported here, which summarizes the results of a published study (Denmark et al., 2019), the quality and amount of facial expression used in the production of a BSL narrative was recorded and analysed. The source material was a BSL narrative produced by respondents after watching a language-less scenario where a girl tricked a boy into eating a bread roll with a spider in it. This scenario forms part of the BSL Narrative Production Test (BSLPT, see Herman et al., 2004). Because the scenario to be narrated in BSL includes events that can lead to emotions classified as ‘surprise’, ‘anger’ and ‘disgust’ in terms of their facial action components, it was considered appropriate material to elicit these expressions. The scenario also included examples of ‘mischief’, ‘refusal’ and ‘demand’. The scenario did not contain emotional expressions for the canonical expressions of ‘happiness’, ‘sadness’ or ‘fear’ (Ekman & Oster, 1979).

Two Deaf adults, who had used BSL since childhood and were therefore deemed good models for BSL purposes, watched the scenario and produced their narrative in BSL: the video record then served as the benchmark for assessing the number and quality of facial gestures made by the children, and their alignment with events in the narrative flow.

Each child's narration was analysed by two independent raters using ELAN software (Lausberg & Sloetjes, 2009) to identify the specific emotional facial actions based on established facial action component criteria (Ekman & Friesen, 1978), and the points in time when they were produced. Scoring criteria included the similarity of the expression to that of the adult models, as well as temporal alignment with the relevant parts of the narrative, and appropriateness and intensity in terms of specific facial movements.

In this study, ten of the original experimental (ASD) group and all control children participated. The instructions – to view the scenario and then 'tell the story' in BSL – were identical to those given in the BSLPT (Herman et al., 2004) and were videotaped for analysis. All children correctly answered three questions concerning the meaning of the scenario, indicating accurate understanding of the story. When their re-tellings were scored using ELAN for BSL narrative correctness, completeness and grammar, the groups did not differ statistically, although ASD grammar scores were poorer, but not significantly so. We can be reasonably confident that any ASD decrement in the use of emotional faces cannot be attributed directly to language-specific differences between the groups.



Production of specific, appropriate emotional facial expressions for ASD and TD groups

Figure 3: Accuracy of facial expression production in the BSL narrative skills test for the designated expressions of 'demand', 'annoyance', 'mischief', 'surprise', 'disgust' and 'refusal', which were produced during the narrative by the BSL models. The experimental group of deaf youngsters with ASD (maroon bars) produced fewer and less specific facial expressions in their narrative productions compared with the deaf controls, except for 'disgust', where they showed more and better NMMs than their deaf controls (pale blue bars). The differences for 'demand' and for 'mischief' were significant (asterisk). Further details reported elsewhere (Denmark et al., 2019).

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Story events requiring emotional facial actions were labelled by emotion or intention (e.g. mischief, refusal), and results are summarized in Figure 3. These show that most ASD scores were generally fewer and less accurate than those for the control group – significantly so for 'demand' and for 'mischief'. In addition, higher SRS scores were associated with lower scores for 'annoyance' and 'mischief'.

'Mischief', while sometimes classified as an emotion, like 'annoyance', usually requires awareness of the other person's state of mind – 'mischief' signalling 'intention to surprise/cause harm', and we note that this was one expression which was affected by ASD both in recognition and in production. 'Disgust', however, was produced more often and more accurately in the ASD group. Why should this be? It is possible that this finding was artefactual: 'disgust' occurred at the end of the scenario - and may have been considered the climax of the narrative, possibly more so by the ASD individuals. However, in hearing people with ASD a similar pattern of relatively better production of expressions of disgust has been reported (Volker, Lopata, Smith & Thomeer, 2009) using different elicitation methods.

The main finding from these two studies exploring facial emotion in deaf children and young deaf people who sign is that ASD affects the processing of facial emotions in dynamic faces. This occurred despite both the typically developing and ASD youngsters performing to an equivalent level on BFRT – a sensitive test of the ability to process images of faces. Not all the tests may have been sufficiently sensitive to draw out possible group differences. Thus, in the perception of videos of signed statements accompanied by the appropriate facial expression, respondents with ASD showed significantly reduced accuracy for just three out of six expressions: ‘happy,’ ‘angry’ and ‘mischief’.

It is likely that the task of processing the manual sign and the facial emotion together was relatively taxing for the group with ASD: the finding that their performance was only slightly more accurate at identifying an emotion when the face was unmasked (see figure 2) supports this conclusion. Similar anomalies were seen in the production task, requiring appropriate facial emotional expressions accompanying signing a video narrative. Here, ASD affected both quantity and quality of the facial expressions produced, especially in relation to the ‘complex’ emotions of ‘annoyance’ and ‘mischief’, which are more likely to engage mentalizing abilities. The finding that ‘disgust’ tends to be displayed by youngsters with ASD to a greater extent and less appropriately compared with controls, suggests that this facial action, when produced by typically developing youngsters, could be moderated by social and intentional factors (and see the Discussion for more on this point).

Part 3 Emotional and Linguistic Facial Actions

a) Production of emotional and linguistic facial actions in sentence imitation. In this experiment (reported in Chapter 6 of Denmark, 2011), respondents were required to watch and then imitate videoclips of a native signer producing a BSL statement which included manual and facial actions. There were 10 sentences with emotional facial actions (‘surprise’, ‘sad’, ‘annoyed’, ‘happy’, ‘disgusted’) and a further 13 sentences with linguistic facial actions (conditional, negation, question). The sentences were presented in a mixed, fixed order with respect to the type of action, with no specific instructions except ‘try to copy what the model is signing as accurately as possible’. Each sentence lasted about 8 seconds and was followed by a blank screen for 4 seconds, before the child produced their version. (See Marshall et al., 2014).

The children's responses were recorded and scored using ELAN by two independent raters. The numbers of correct 'emotion' and 'linguistic' facial actions did not differ significantly in the two groups. However, the quality of the actions did differ. The typically developing group produced more face actions rated identical to those of the model: the ASD group produced face actions which were rated similar - but not in every detail. For example,

> "[…] a *deaf individual with ASD producing a linguistic sentence using negation…only produces one facial expression target out of a possible three: lip protrusion, she does not furrow her eyebrows or shake her head negatively. Similarly a deaf boy with ASD …produces an affective sentence conveying sadness (HE LEFT YESTERDAY),… demonstrates 2 out of 5 facial targets, with furrowed eyebrows and a down turned mouth, however he omits 3 target facial actions including: eyebrows, head nod and head shake[…]"* (Denmark, 2011, p 158.)

Thus, one or other of the typical face actions was missing a specific facial action, or the ASD respondent produced one which was not of the same intensity as the model or otherwise approximated to the required action.

b) Understanding and producing linguistic facial actions conveying grammatical information on the face: adverbs, negation, and questions. In hearing children with ASD who use spoken English there are reports of difficulties in relation to some aspects of language production. They ask fewer wh-questions and can appear to have difficulty in posing all types of spoken questions rather than statements, developing these skills later than typically developing children (Goodwin, Fein & Naigles, 2012). Facial and other gestures can be affected when hearing children with ASD imitate actions of others – especially when the action style is not intrinsic to the goal (Hobson & Hobson, 2008).

Functions such as questions and negation are marked with a facial action in SLs, produced concurrently with the manual action. Similarly, concurrent articulation of facial and manual gestures can indicate the manner and/or scope of an action in SL adverbs. Could the requirement to take account of facial actions in SLs moderate the processing of facial actions in deaf children who use a SL? In particular, would the requirement for such linguistic facial actions impact children with ASD to a greater extent than the control group?

The tests used are briefly indicated in the table below, and the results summarized below that. Denmark (2011) provides further details.

For the comprehension tasks, BSL actions were shown to the children in video clips. They were posed by an adult native deaf BSL sign user (the BSL model), and presented one item at a time for response. The response required was to choose from one of two pictures presented (adverbial, negation tests). For the question comprehension task, the child had to indicate if a statement or a question was posed by the model and, if so, whether it was a 'yes/no' or a 'wh' question. For the production tasks, the response required the child to make appropriate facial actions to distinguish pairs of pictures of events (adverbials, negation). For question production, only 'yes/no' questions were elicited (see table 1 for summary details). The children were given instructions in BSL and tested for their comprehension before the tests were run. All the children's productions were videotaped and scored by 2 independent raters using ELAN. Rater agreements were above 90% in all cases (Denmark, 2011).

Table 1 Summary of Tests of Linguistic NMMs

	Adverbial	Negation	Questions (both WH and Yes/No)
Comprehension	BSL modelled RUN, CARRY and BICYCLE combined with facial adverbials MM, INTENSE,PUFF,CHA and PS to form 39	BSL modelled a series of actions describing one of a pair of pictures, where one was a statement , the other negated it (e.g. BOY	1)BSL modelled a series of questions and commands about the spatial layout of objects (e.g. 'RED TRIANGLE WHERE ?; BLUE SQUARE NEXT) for subject to respond appropriately

	sentences describing target pictures. Subjects made a choice between a pair of pictures (target and distractor)	APPLE EAT vs BOY APPLE EAT headshake face NOT). Subjects responded by pointing to one of two pictures (Atkinson et al., 2004)	2) BSL model produced a series of commands and questions Subjects responded by choosing whether what was signed was a 'command'(17 statement items) or 'question'. If they chose 'question' they were then asked to distinguish 'tell' (for YES/NO, 19 items); or '?'(for WH- 14 items).
Production	18 Pictures which required adverbial BSL production were shown in pairs for subjects to describe using BSL. First picture (neutral) did not require modification. The second showed a similar situation but did require (adverbial) modification. Subjects facial responses were scored for number, accuracy and quality	Produce a BSL description of the pairs of statement/negation pictures used in the classification task. Responses scored for number, accuracy, and quality of responses	*YES/NO only* Subjects were engaged with Experimenter in a 'Guess who' game, where the goal was to identify a pictured individual held by the Experimenter by asking questions (eg YOUR PERSON SPECTACLES?). Subject's questions were scored for facial and head actions produced.

(From Denmark, 2011).

The results are readily summarized. For the negation and question tests, ASD and controls performed similarly. As well as similar median responses, reaction times for comprehension were similar for the two groups, and the groups could not be distinguished in how they produced these types of facial actions. That is, under these specific conditions, where deaf children and young people with ASD matched for age, intellectual abilities and BSL with a control deaf group, and were asked to classify and produce negation and questions using facial acts, no group differences were found in the speed, accuracy, number or appropriateness of the gestures examined.

For adverbials, however, the ASD group performed worse than controls, especially when a face-only condition was contrasted with a face+manual condition. While the control group performed equally well (90%+) with both conditions, the children with ASD were worse when face alone was seen (62%) compared with face+manual (90+%). Similarly, when children with ASD produced short narrative descriptions of a photograph designed to elicit the use of facial adverbials, fewer were produced in the ASD group.

Discussion: Linguistic NMMs in youngsters with ASD: The group sizes and range of scores were sufficient to detect group differences at a statistical level. The task conditions varied, encompassing repetition and production, as well as several comprehension tasks. No overall differences were detected when the ASD group was compared with their controls for specific tests of negation and questions. Facial adverbials were more difficult for the ASD group, both in comprehension and production. While there is some evidence for morphosyntactic anomalies and less complex linguistic structures in the speech of young hearing children with autism (Eigsti, Bennetto & Dadlani, 2007), as far as we know no specific studies indicate that adverbial modifications are implicated. Is it possible that the facial adverbials used in these SL tests carried components of the signer's intentions and emotions – that is, they carried emotional/intentional colouring which may have been less accessible to the children with ASD? For example, in hearing children with autism, there can be difficulties in understanding aspects of human motor actions that are not 'purely' functional, but may involve different degrees of 'effort' in the conversational partner (see e.g. Boria et al., 2009).

Further analysis revealed some more differences between autistic and non-autistic deaf children, especially in production. The qualitative nature of the facial actions of deaf autistic children deviated in terms of intensity and timing with a sometimes-stilted quality. In imitating signed utterances requiring both linguistic and emotional facial actions some in the ASD group made fewer facial actions that were identical to those of the model (Chapter 6 of Denmark, 2011). Their facial actions were 'similar' but might miss one of the constituent actions, or the intensity of the action was slightly different than that of the model.

These imitation tasks required respondents to co-ordinate face and manual actions precisely, which was less of an issue in the studies which explored specific linguistic facial actions, where responses made by the participants were more constrained. It is plausible that the integration of hands and face in understanding and producing a SL may be more problematic for people with ASD than for typically developing people – in line with the suggestion, in hearing people with ASD, that managing spoken intonation combined with linguistic processing can be difficult (Järvinen-Pasley, Peppé, King-Smith & Heaton, 2008). Similarly, Denmark notes

> " […] *Anecdotally it was noted by the experimenter that when the participants in the deaf ASD group were given the three questions at the end of the BSL narrative skills test (see Chapter 5) they had difficulty recognizing that they were being asked a question […]*" (Denmark, 2011, p 223).

Difficulties in motor co-ordination across the two-articulation system may have played a role in these findings. A case study of a young hearing man with autism who learned sign language suggested that his sign language co-ordination was poor. (Smith, Woll, Morgan & Tsimpli, 2002) Dyspraxia is commonly associated with autism (Cassidy et al., 2016).

A further consideration is that corpus studies which collect examples of natural SL production suggest facial actions marking negation and question type may vary to a greater extent within individuals and across sign languages than might be supposed from standard descriptions of the canonical, formal structures widely cited in sign language literature (Bauer & Kyuseva, 2021; de Vos, van der Kooij & Crasborn, 2009; Johnston, van Roekel & Schembri, 2016). Our essentially null findings concerning the impact of ASD in linguistic NMMs of negation and question type[5] should be viewed in this constrained context. More naturalistic studies might find different results and more subtle patterns of impairment or difference.

Part 4 Discussion

Anomalies in processing faces and facial actions have been reported for hearing people with ASD. Our research sought to establish whether deaf children and young people with ASD show similar patterns and whether this affects their ability to use and comprehend the aspects of sign language that rely on dynamic facial processing. We were interested in whether they would show a global difficulty in face processing while understanding or using sign language, in which case both emotional and linguistic facial actions would be impaired, or alternatively, in line with findings for hearing children with ASD, whether they would show a selective deficit for emotional faces, compared with linguistic facial actions. We found more evidence for the latter account. The deaf ASD group did not show primary face processing difficulties in face recognition (BFRT). They did show some differences from the control group in comprehension of some emotions (including 'mischief', which requires mentalizing skills), and were less sensitive to facial information (see Figure 2). For linguistic faces in BSL, they were somewhat impaired in imitating SL utterances that required facial modifications of manual actions, and they were less able than controls to process facial information conveying adverbial manner ('carelessly', 'effortfully'). That is not to say that such actions were ignored – however they were managed less efficiently. The ASD group showed no differences from the control group in processing linguistic facial actions of negation or question type while watching dynamic faces during sign language comprehension and production tasks. In the light of these findings, we suggest that the use of sign languages may have a moderating

[5] A further consideration is that, for question comprehension, respondents (especially the younger ones) were not assessed for their specific understanding of spatial arrays of (highly abstract) colored shapes. Future studies should carefully assess understanding of the materials used in such tests.

influence on the development of some face processing abilities in ASD, and protect to some extent from the anomalies typically found in hearing children with ASD.

It is important to consider the matching criteria used. These young people were paired for BSL abilities, non-verbal intellectual ability (Raven's matrices) and age. The deaf children and young people who served as controls for the youngsters with autism were therefore not typical of most young deaf people in terms of their intellectual abilities. Moreover, anomalies like those for ASD in processing emotion have been reported in other behavioral conditions in hearing populations, including attention deficit disorder and developmental language delay (Löytömäki, Ohtonen, Laakso & Huttunen, 2020), and we did not screen for these. These factors may have contributed to the lack of a specific effect of ASD on face processing and face action processing in the present study.

Conclusions and directions for research

To conclude: firstly, a standard test of facial identity recognition (BFRT) showed no group differences in these deaf youngsters with autism, compared with their matched deaf controls. This is in contrast to reports that face recognition can be impaired in hearing youngsters with ASD (Annaz et al., 2009; Klin et al., 1999). What remains to be shown is whether, if ASD and non-ASD *hearing* participants were matched in a similar way, this might eliminate the face processing anomalies between the two groups. ASD may yet have some effect on this task, depending on group matching criteria used. But as far as the present study is concerned, the finding that our current group of ASD respondents could not be distinguished from controls in this way set the scene for further studies.

In line with the general autism literature, the deaf ASD group did show some deficits in processing emotion on the face during sign language tasks – for both production and perception. When they watched short manually signed statements with neutral content that were accompanied by different facial emotions, the control group were more accurate in classifying the emotion displayed than those with ASD – for some, but not all, emotions. While masking the face affected controls, it had less effect on the ASD group, who may use strategies that are less reliant on facial information to process affective information from the utterance. It is plausible that the use of atypical strategies is why they show less efficient emotion recognition when facial information is available, and faces are not obscured. Further tests would be needed to examine whether simple classification of facial emotion is affected when the face images are seen as static photographs - or as video shots with no manual component.

The ability to produce emotional or intentional face expressions while signing was also affected by ASD. The group with ASD showed difficulties with conveying expressions that required an understanding of another's mental state such as 'mischief' and 'annoyance'. They also tended to display 'disgust' to a greater extent than the controls when re-telling the 'Spider' story using BSL. Interestingly, 'disgust' tends to be accurately interpreted at a later developmental stage in (hearing) children than 'happy, 'sad' and 'angry'(Widen & Russell, 2003), yet this autistic sample displayed more 'disgust' in their narratives. Disgust is an emotional response with evolutionary benefit in avoiding contagion or contamination and is associated with behavioral avoidance of potentially dangerous stimuli. It appears to be a universal emotion in its expression characteristics, including in people born blind (Darwin, 1872, 1998), although it can require visual experience in order to be expressed voluntarily (Valente, Theurel & Gentaz, 2018). In children with OCD, there is heightened sensitivity to disgust (Widen & Olatunji, 2016), and it is possible that the concept of 'disgust' may configure differently in people with ASD compared with others. For example, one possibility is that people with autism may find the events displayed in the scenario more arousing ('disgusting') than control populations, in line with their issues in relation to food choice and sensory processing (Zulkifli, Kadar, Fenech & Hamzaid, 2022). An alternative explanation may be that the scenario which depicted a spider placed inside a sandwich was less likely to be interpreted by the ASD group as a practical joke or an act of revenge, due to difficulties with mentalizing. It is also possible that the range of moral and ethical aspects of disgust may be processed differently in people with ASD than in control populations (Zalla, Barlassina, Buon & Leboyer, 2011). In typically developing individuals, 'disgust' is often inhibited for social reasons (Lwi, Haase, Shiota, Newton & Levenson, 2019), and people with ASD may be less able to manage this (see e.g. for 'sadness' (Wallace et al., 2011)). Young people with autism may show heightened processing of disgust because they are less sensitive to other moderating factors including social inhibition, and (in the narrative production case) the dampening effect of other explanations for a spider in a sandwich.

A further point of difference was in the quality of all emotional expressions. ASD respondents tended to show fewer of the required facial actions; their face actions were similar, but not identical, to those of the model. A similar pattern has been noted in hearing children with ASD (Trevisan et al., 2018). A contrast between deaf and hearing children with ASD would be instructive for future research.

Our autistic sample did not show difficulties with the linguistic use of facial actions within BSL for questions and for negation. While the results for the question tasks are suggestive, they are hardly conclusive, and require much fuller investigation (see Denmark, 2011, for further discussion). Moreover, in both question and negation comprehension tasks, responses were highly constrained. Thus, for negation, respondents simply distinguished between two objective states – either '(e.g.) BONE THERE or BONE THERE headshake-NOT'. Negation is more often employed in complex scenarios - for instance to mark an absence where a presence might be expected, or any number of more pragmatically complex constructions ('Oh not me, I couldn't possibly…'). People with ASD are not usually impaired in logical exposition or understanding; problems tend to arise where the pragmatics of an utterance need to be interpreted or expressed correctly (Schindele, Luedtke & Kaup, 2008). In order to assess whether deaf signers with autism show these problems, the tests of linguistic facial gestures will need to be extended into less constrained settings. One indication that ASD may impact on NMM production was the finding that in posing YES-NO questions, ASD respondents used fewer and less complete facial actions than the control group. This was the only condition which was not constrained in terms of the experimental requirements for processing questions.

The processing of the facial adverbials was the one aspect of linguistic processing that indicated anomalous processing in the ASD group – both in comprehension and production. One reason for this could be that the classification of the facial gestures as ‘adverbial’, while informative in relation to spoken language, may be misleading in terms of SL, where a better description may simply be ‘experiential modifier’ – the particular modification being an indication of how the signer experiences or feels the action described either from their own point of view or to show the experience or behaviour of another person through embodied action (e.g. ‘It’s heavy..’; ‘…she was careless…’), which can involve perspective taking, and may rely on mentalizing skills. If so, we may predict that ASD impacts on this ability and hence on processing these particular facial gestures. There is some evidence that this can be an issue for hearing people with ASD in relation to understanding the movements of a conversational partner (Cattaneo et al., 2007; Hamilton, 2009; Sabbagh, 1999).

But for now, our studies show that children and young people with ASD who use BSL can and do make use of faces and facial actions, both in relation to their sign use and more generally. While we found evidence of some autistic traits similar to those that have been reported in hearing speaking young people with ASD, for example in coordinating facial and manual actions for comprehension and production, as well as possible difficulties in tasks which may include (implicit) mentalizing strategies, they do not appear to have a general ‘difficulty with faces’. The findings of the current study, while not conclusive, suggest that the requirements of sign language processing may give the deaf children and young people with ASD an advantage over their hearing peers in processing faces and their actions.

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Acknowledgements

This work was supported by the UK Economic Social and Research Council as a 1+3 funded Ph.D. stipend awarded to Tanya Denmark. Joanna Atkinson was supported by grants from the Economic and Social Research Council of Great Britain (RES-620-28-6001 and RES-620-28-0002) to the UCL Deafness Cognition and Language Research Centre (DCAL).

We are grateful to colleagues at UCL and DCAL: Adam Schembri and Bencie Woll for advice regarding coding of sign language, sign language linguistics and atypical deaf sign language users; David Vinson and Paul Bassett for statistical advice, Michael Coleman for programming the comprehension tasks. We thank Robert Adam, Kate Rowley and Mischa Cooke for acting as adult sign language models and Ramas Rentelis for assisting with second-coding of the data. We are grateful to Tyron Woolfe, Pam Morgan, Jordan Fenlon, Clark and Carolyn Denmark who modelled the photographs used in the work.

We also thank Judy Reilly for offering input and methodological advice and allowing adaptations to her original study, and to Constanza Moreno for clinical input and support. Finally, we thank all the children, schools and parents who participated in and supported this research study.