Journal of Child Language (2023), 1–34
doi:10.1017/S0305000922000745

ARTICLE

Development of sign phonology in Kata Kolok

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(Received 12 February 2021; revised 21 October 2022; accepted 18 November 2022)

Abstract

Much like early speech, early signing is characterised by modifications. Sign language phonology has been analysed on the feature level since the 1980s, yet acquisition studies predominately examine handshape, location, and movement. This study is the first to analyse the acquisition of phonology in the sign language of a Balinese village with a vibrant signing community and applies the same feature analysis to adult and child data. We analyse longitudinal data of four deaf children from the Kata Kolok Child Signing Corpus. The form comparison of child productions and adult targets yields three main findings: i) handshape modifications are most frequent, echoing cross-linguistic patterns; ii) modification rates of other features differ from previous studies, possibly due to differences in methodology or KK's phonology; iii) co-occurrence of modifications within a sign suggest feature interdependencies. We argue that nuanced approaches to child signing are necessary to understand the complexity of early signing.

Keywords: sign phonology; feature analysis; typology; Kata Kolok

Introduction

Most deaf children in Western countries are born to hearing parents and receive delayed input in a signed language (Hall, 2017; Mitchell & Karchmer, 2004). If deaf children have access to fluent signing from birth, i.e., the few that are born to deaf parents, they reach linguistic milestones around the same age as their hearing peers. These parallels are particularly notable given that signing children use a very different articulatory apparatus and perceptual channel; signing children coordinate two articulators, i.e., two hands, and learn to master a linguistic system in the visual-spatial modality (Lillo-Martin & Henner, 2021; Pichler, 2012). Despite these differences, signing children, much like hearing children, start out with manual babbling and progress in acquiring sign phonology as their productive lexicon expands (Cheek, Cormier, Repp & Meier, 2001; Lillo-Martin & Henner, 2021; Pichler, 2012).

Sign language phonology refers to the sub-lexical organisation of signs. Initially, signs were described in terms of four parameters: handshape, location, movement, and orientation (Battison, 1978; Stokoe, 1960). Since the 1980s, researchers have turned to a more fine-grained feature analysis of signs for theoretical models of sign phonology due to the lack of a consistent one-to-one correspondence between parameters and nodes in hierarchical models (Brentari, 1998; Sandler, 1989; van der Kooij, 2002)[1]. For this study, we adopt the *Dependency Model*, originally developed by van der Hulst (1995) and van der Kooij (2002). This model is based on the idea that the segmental structure of signs unfolds around handshape and place of articulation features. For a visualisation of the Dependency Model with feature values, see Appendix A.

Sign can be described on the level of features (see Table 1 for examples). Signs involve one hand (CANDY or BRIGHT) or two hands ('handedness') that either symmetrically mirror each other (BICYCLE) or are asymmetric by using a static non-dominant hand as the place of articulation (BANANA). Each hand has a certain configuration, or 'handshape', which specifies selected fingers and their position ('finger selection', 'finger configuration', 'unselected fingers', 'spreading', 'aperture'), and some signs include 'handshape changes' such as *closing* and *opening* of the fingers (BRIGHT). The place of articulation, or 'location', denotes where a sign is produced, i.e., in *neutral space* (BICYCLE), on the *body* (CANDY) or the *non-dominant hand* (BANANA), and relates to the 'type of contact' between the hand(s) and the body (e.g., *continuous* in BANANA). Movement features capture spatial displacement of the hand(s), describing the 'movement shape' (e.g., *circle* in BICYCLE vs. *straight* in BANANA) and the 'movement direction' (e.g., *downwards* in BANANA vs. *forwards* in BICYCLE).[2] Nevertheless, movement features are not always applicable in that not all signs include non-NA values for these features (e.g., CANDY or BRIGHT). The orientation of the selected fingers is expressed in relation to the movement ('orientation movement') and the location ('orientation location'), and signs may include 'orientation changes' of the palm, e.g., *flexion* or *supination.* Lastly, *non-manual* features describe all those elements of a sign that are produced on the face and body, particularly actions of the mouth. These are commonly differentiated in silent imitations of speech ('mouthings') and speech-unrelated mouth movements ('mouth gestures') such as *biting* in CANDY and a *lip smack* in BRIGHT (Crasborn, van der Kooij, Waters, Woll & Mesch, 2008).

In spite of analysing sign language phonology on the feature level since the late 1980's (Sandler, 1989), and evidence that speaking children acquire features or even clusters of features rather than phonemes (Jakobson, 1968; Smith, 1973; for more recent overviews see Fikkert, 2007; Dresher, 2004), research on the acquisition of sign phonology predominately examines the three parameters handshape, movement, and location (Boyes-Braem, 1990; Cheek et al., 2001; Clibbens & Harris, 1993; Conlin, Mirus, Mauk & Meier, 2000; Karnopp, 2002; Lavoie & Villeneuve, 2000; Marentette & Mayberry, 2000; McIntire, 1977; Meier, 2006; Meier, Mauk, Cheek & Moreland, 2008; Morgan, Barrett-Jones & Stoneham, 2007; Siedlecki & Bonvillian, 1993; Takkinen,

[1]For the purpose of this study, we use the term 'feature' to refer to the articulatory dimensions borrowed from Global Signbank, and more broadly, from the Dependency Model, e.g., 'handshape dominant hand', 'location' or 'movement direction'. Manifestations of these features such as *circular* or *straight* for 'movement shape' are referred to as feature values.

[2]Parameter analyses of signs collapse several different features into the movement parameter: displacement between location A and location B is referred to as path movement while changes in handshape or orientation are conflated as hand-internal movement.

https://doi.org/10.1017/S0305000922000745 Published online by Cambridge University Press

Table 1. Selected signs and their feature description, detailing features on the left and the respective feature values for each sign on the right. Signs from the KK dataset in Global Signbank (Crasborn, Zwitserlood, van der Kooij, & Schüller, 2018; Lutzenberger, 2020).

				
Hands (Handedness)	2 asymmetric	2 symmetric	1	1
Handshape	1	S	Baby_beak	Beak
	Baby_beak	S		
Finger Selection	Index	none	Index	Index-Middle-Ring-Pinky
Finger Configuration	extended	NA	NA	extended
Spreading	NA	NA	NA	unspread
Aperture	NA	closed	closed	closed
Handshape change	NA	NA	NA	open
Location	non-dominant hand: index finger	neutral space	mouth ipsilateral[3]	neutral space
Movement shape	straight	circle	NA	NA
Movement direction	downwards	forwards	NA	NA
Orientation (Location)	palm	palm-down	palm-inwards	palm-forward
Orientation (Movement)	base	NA	NA	NA
Orientation change	NA	NA	NA	NA
Contact	continuous	NA	continuous	NA
Non-manuals	NA	NA	bites	lip smack

2000; Von Tetzchner, 1984).[4] This has created a methodological and theoretical gap between our knowledge about sign phonology and its acquisition as well as between the acquisition of signed and spoken phonologies.

In this study, we do not only set out to close this gap by adopting a feature approach but also broaden the typological range of languages studied by focusing on Kata Kolok (KK), the sign language of a Balinese village. Studies on the acquisition of sign phonology have focused on sign languages used in urban, mostly Western contexts. Here, we study the acquisition of one of the oldest documented sign languages arising in the context of an isolated, rural community (de Vos, 2012a; Marsaja, 2008).

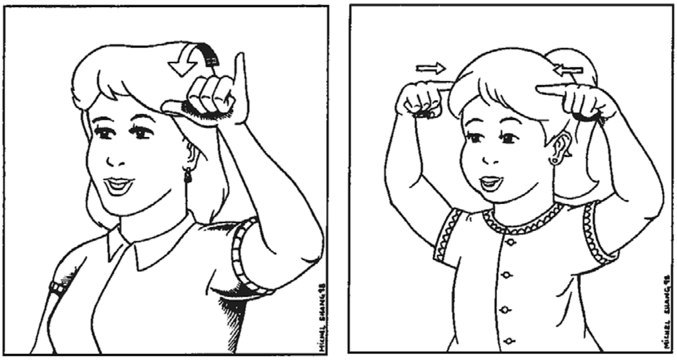
The contribution of this study is thus two-fold: i) we present a feature analysis of child modifications on par with adult data, applying the same feature coding used in a lexical database to acquisition data. This allows for more direct comparisons of child productions to the target phonological system of adult signers and paves the way for direct comparisons with the acquisition of spoken phonology in the future. ii) By studying KK, we broaden our knowledge about the acquisition of sign phonology and enable future cross-linguistic comparisons testing the robustness of acquisition patterns. The paper is structured in three sections. First, we review research on the acquisition of sign phonology and provide a sketch of KK and its community. After contextualising the present study and explaining the methodology, we present quantitative and qualitative results of a feature analysis and a sign-level analysis. The paper ends with an elaborate discussion of typological implications of our findings, limitations of the study and avenues for future work.

L1 acquisition of sign phonology

Previous studies have focused on three parameters: handshape, location, and movement (path movement and hand-internal movement). Various types of evidence suggest that handshape is the most complex parameter (Sandler & Lillo-Martin, 2006); handshape is most prone to slips of the hands (Hohenberger, Happ & Leuninger, 2002; Klima & Bellugi, 1979; Newkirk, Klima, Pedersen & Bellugi, 1980) and to errors in hearing adult L2 signers (Ortega & Morgan, 2015), and the only parameter that is perceived categorically (Best, Mathur, Miranda & Lillo-Martin, 2010; Emmorey, McCullough & Brentari, 2003). Similarly, children seem to master handshape last, preceded by location and movement (Conlin et al., 2000; Karnopp, 2002; Marentette & Mayberry, 2000; Morgan et al., 2007; Siedlecki & Bonvillian, 1993). Nevertheless, inherent complexities of parameters are linked to the child's maturing motor system and developing mental representations in L1 acquisition (Conlin et al., 2000; Meier et al., 2008; Ortega & Morgan, 2015). Meier and colleagues (Meier, 2006; Meier et al., 2008) argue for robust articulatory effects; movement errors align with general motor development, explaining the use of more proximal than distal joints, movement assimilation and repetition. Although gross motor control may explain the high accuracy of location even in early

[3]Ipsilateral and contralateral side are specified according to whether the location lies on the same side of the body or crosses the body midline; when the hand crosses the body midline, the location is specified as *contralateral*, else as *ipsilateral.* For example, placing the right hand on the right earlobe is referred to as *ipsilateral earlobe*, placing the right hand on the left earlobe as *contralateral earlobe.*

[4]Note that some studies include aspects of orientation or contact, e.g., Siedlecki and Bonvillian (1993) include 'contact' and Cheek and colleagues (2001) orientation and handedness of signs.



COW

Figure 1. Example of a child modification in American Sign Language (ASL) in the sign cow. Adult target on the left, child modification on the right (from Marentette & Mayberry, 2000, p. 84). [reprinted with permission from Paula Marentette and Rachel Mayberry].

signing (Conlin et al., 2000; Siedlecki & Bonvillian, 1993), Marentette and Mayberry (2000) propose that variation in the mastery of body locations suggests that children construct a body scheme.

Like early speech, early signing is characterised by systematic modifications. Across all parameters, modifications can be summarised as: i) substitutions i.e., replacing one value for another; ii) additions, i.e., adding a value; and iii) omissions, i.e., dropping a value.

Handshapes are often substituted for other handshapes (American Sign Language: Boyes-Braem, 1990; Cheek et al., 2001; Marentette & Mayberry, 2000; McIntire, 1977; Siedlecki & Bonvillian, 1997, 1993; British Sign Language: Clibbens & Harris, 1993; Brazilian Sign Language: Karnopp, 2002; Finnish Sign Language: Takkinen, 2000; Norwegian Sign Language: Von Tetzchner, 1984). Specifically, cross-linguistic studies (partly) support predictions derived from a model of handshape acquisition based on articulatory and cognitive constraints according to which easy handshapes such as *B, 1* or *5*[5] are acquired first and are frequently used to replace more complicated ones such as *ILY* or *Y* that are acquired later (Boyes-Braem, 1990; Conlin et al., 2000; Marentette & Mayberry, 2000). For example, the ASL sign cow in Figure 1 includes a substitution and simplification of handshape: the handshape used by the child (*1)* is less complex than the adult target (*Y).* In addition, children often drop or add the second hand (Figure 1). More recent research on the acquisition of handshape features in Hong Kong Sign Language suggests that children acquire the feature value *extended* ('joint position') such as in handshapes *B, 1, 5* early (Pan & Tang, 2017; Wong, 2008). In asymmetric two-handed signs, children may create symmetry through assimilating handshapes and movements (Cheek et al., 2001; Conlin et al., 2000; Marentette & Mayberry, 2000; Siedlecki & Bonvillian, 1997; Takkinen, 2000).[6] This strategy circumvents having to coordinate two

[5]Throughout this paper, we refer to handshapes in letters and numbers, following the convention introduced by KOMVA (1988) and used in Global Signbank. Images of handshapes can be found on Global Signbank under: https://signbank.cls.ru.nl/handshapes/show_all/. An overview of all handshapes mentioned in this paper can also be found in Appendix B.

[6]Video examples from Jolanta Lapiak under https://www.youtube.com/watch?v=1P-NajjOcdU.

https://doi.org/10.1017/S0305000922000745 Published online by Cambridge University Press

hands independently of each other and may resemble assimilation or reduplication in speech acquiring children (Fikkert & Levelt, 2008).

Locations are often substituted for larger locations (Morgan et al., 2007), such as *head* instead of *temple* in COW (Figure 1). Whether location substitutes are bigger and more salient than adult targets, as Marentette and Mayberry (2000) propose, remains to be corroborated. In terms of movement, children often enlarge, omit, or repeat path movement and omit or substitute hand-internal movement (Meier, 2006). For example, replacing *flexion* of the wrist with *flexion* of the elbow results in a larger movement in child signing (e.g., Figure 1), a pattern that has been linked to a preference for more proximal joints in children (proximalization; Meier, 2006; Meier et al., 2008). Moreover, modifications of movement size (and speed) and movement repetition have also been identified as characteristics of child-directed signing (Holzrichter & Meier, 2000; Pizer, Meier & Points, 2011).

Characteristics beyond the parameters handshape, location, and movement have remained largely unexplored. Observations about the role of contact have been made in multiple studies but never studied in detail. Siedlecki and Bonvillian (Bonvillian & Siedlecki, 1996; Siedlecki & Bonvillian, 1993) notice that many child signs rely on contact, possibly for sensory feedback. Boyes-Braem (1990) reports a preference for fingertip contact whereas Conlin and colleagues (2000) find loss of contact in a small number of signs. In short, evidence about the role of contact is inconclusive due to a lack of focused investigation. In addition, parameters have been studied in isolation with a focus on the number and the type of error and exact substitution patterns. The example provided in Figure 1, however, suggests that the child modifies multiple features within the same sign: here handshape, location, and movement. The focus on isolated parameters may have obscured developmental patterns such as potential feature interdependencies and the larger scope of features over phonemes as reported for speech-acquiring children (Fikkert & Levelt, 2008).

Summing up, studies have investigated three parameters – handshape, location, and movement – and determined the order of acquisition based on error rates. Child errors are summarised as substitutions, omissions and additions. Studies show that easy handshapes, repeated, deleted or enlarged movements, and larger locations than in the adult target are characteristics of child signing. Handshape acquisition yields cross-linguistic similarities in substitution patterns that may be explained by articulatory and cognitive development; movement and location errors have been strongly linked to immature motor control or/and a developing body scheme. Despite the wealth of studies, our knowledge is limited to a small range of sign languages, most of them used in urban, Western contexts, particularly ASL and British Sign Language (BSL).

Kata Kolok

KK is a sign language isolate used in a single farming community of ~3,000 inhabitants in rural Bali, Indonesia (Marsaja, 2008; census data 2019). Sustained hereditary deafness facilitated the emergence of this language six generations ago (de Vos, 2012a; Winata et al., 1995). Since its emergence, KK has developed into a main language of communication among the villagers without influence from any other signed or spoken language (de Vos, 2012a).

As other rural communities in Bali, the village community is a tight-knit community whose social structures are dominated by kinship relations in patrilineal tradition

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(Marsaja, 2008). Birth determines membership to one of the ten village clans and women transfer to the husbands' clan through marriage. Within clans, family compounds create shared courtyards where children grow up with age-related peers from their own and adjacent family compounds. Households are often multi-generational and childcare responsibilities are shared with the elderly and older siblings.

Communal living in family compounds combined with the high rate of deafness and positive attitudes towards KK led to a high proportion of hearing signers with various degrees of proficiency (Marsaja, 2008). With family members, neighbours, and peers who can sign, deaf children are exposed to a large range of signing interlocutors in all situations of daily life (de Vos, 2012b). The received input of both child-directed and overseen KK starts immediately after birth and is continued throughout life. This kind of rich and diverse linguistic environment resembles to some extent how hearing children acquire their first (spoken) language.

Since deafness first occurred in the village, deaf children have been born in all clans (Marsaja, 2008). Recently, families with deaf children have relocated to other parts of the island or even abroad due to the changing socio-economic circumstances. Currently, a deaf child born in 2014 is the only deaf child signer of generation VI who lives in the village. Relationships of deaf generation V signers have resulted in several hearing children who acquire KK from birth as bimodal bilinguals. Together, these hearing and deaf children build a strong peer group with KK as L1.

Research on the structure of KK has revealed several typologically unusual features in the lexicon. Most relevant to this study, the range of 'location' values occupies a broader area of space and of the body than in many sign languages and the KK lexicon consists of a relatively small set of basic 'handshapes' (de Vos, 2012a; Marsaja, 2008), similar to other small sign languages emerging in isolated communities.

Concluding, KK is a sign language isolate exhibiting typological rarities especially in terms of use the phonological features 'location' and 'handshape'. The community structure leads to a rich and diverse acquisition environment for deaf children. However, the acquisition of KK remains to this point almost unexplored (notable exception de Vos, 2012b).

Present study

Although substantial research has been focused on the acquisition of sign phonology, we see three issues in this field that merit an innovative approach. First, research on the phonology of sign languages and on its acquisition appears disjointed: while the former consists of feature analyses since the 1980s, the latter often remains on the investigation of phoneme-like parameter values. Although several acquisition studies had initially coded for articulatory dimensions that overlap partly with how adult signing is coded (e.g., Conlin et al., 2000; Marentette & Mayberry, 2000), publications often focus on handshape, location, and movement; and coding schemes used to study phonology based on adult data are not extended but modified for the study of child data. Second, speaking children show feature dependencies in their acquisition, i.e., the acquisition of certain features often depends on other features (Davis, MacNeilage & Matyear, 2002; Fikkert & Levelt, 2008), and examples from previous literature on sign acquisition suggest deviations of multiple feature values within a sign (Figure 1). Even though features (or parameters) are by necessity expressed simultaneously in signs, studies have often investigated them in isolation, potentially obscuring crucial links between different

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features. Third, studies investigate the phonological acquisition of native-signing children learning sign languages used in contexts where most deaf children are born to hearing non-signing parents and grow up in large and loose networks of signers in urban areas (Lillo-Martin & Henner, 2021; Mitchell & Karchmer, 2004). The acquisition by deaf children growing up in tight-knit, rural communities with high incidences of deafness is severely understudied.

The present study addresses the question as to what characterises early phonology in KK. Using longitudinal corpus data from four deaf children acquiring KK as L1, we analyse feature modifications qualitatively and quantitatively and provide insights into the co-occurrence of feature modifications within child productions. The aim of this paper is therefore two-fold: first, expanding the typological range of languages studied for acquisition by contributing novel data from an understudied language; second, bridging the methodological and theoretical gap between sign phonology and its acquisition through a preliminary analysis of child productions that i) adopts the identical feature analysis used in a lexical database of adult signing, and ii) investigates child productions on the sign level. We do not provide a full-blown parameter-based analysis of the current data because we believe that analysing child signing on par with adult signing is a timely and necessary endeavour. Instead, we include a case study on movement that exemplifies how analyses under those different approaches may compare to each other by providing an overview of methodological differences across selected studies adopting feature coding/analyses.

Method

Participants

This study comprises data from four deaf children (3 female, 1 male) whose only language is KK. Parents of all children are deaf, except CSC's father who is a hearing man from a different village.

The four children are part of two big deaf families in the village and belong to two subsequent generations (Figure 2): SS and P3 are generation V signers; CSA and CSC are generation VI signers. For all children, most immediate family members are deaf. SS and

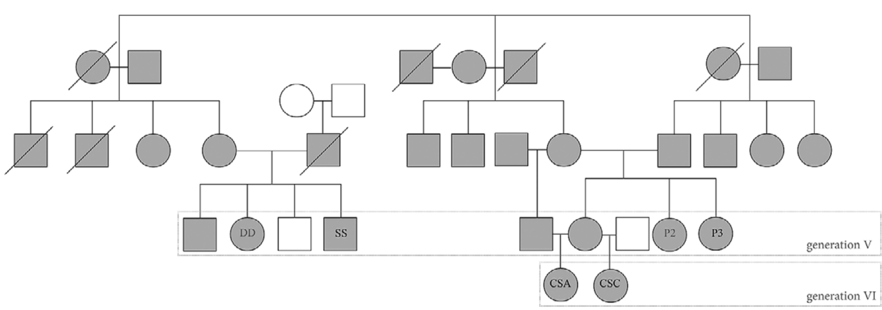

Figure 2. Family tree indicating the relation of the four focus children SS, P3, CSA, and CSC and the research assistants DD and P2; deaf individuals are marked in grey and hearing in white. Circles stand for female individuals and squares for male individuals. Filled symbols stand for deaf individuals and empty symbols for hearing individuals. Slashes through a symbol indicate that an individual is deceased. Horizontal lines indicate same-level kinship, vertical lines indicate offspring.

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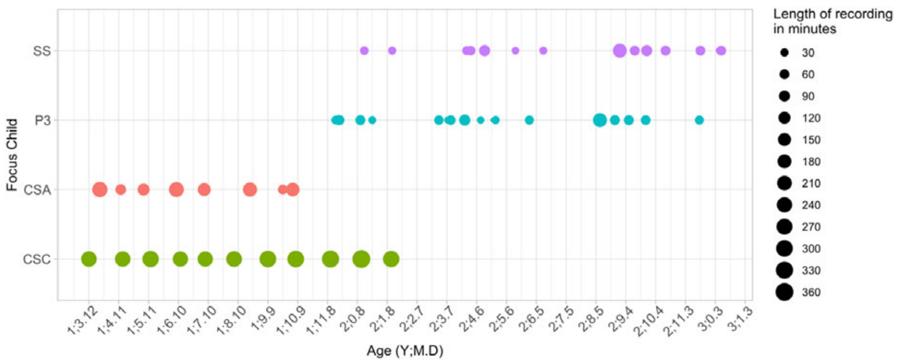

Figure 3. Overview of recording sessions of the current sample.

P3 have deaf parents and older deaf siblings. SS has been raised in the same house with a hearing sibling and hearing grandparents. All members of P3's household are deaf. Although growing up in different households, SS and P3 have been socialised together since birth through their parents' occupational duties. CSA and CSC, nieces of P3, are half-sisters and have been living predominately in their mother's family compound, the same as where P3 grew up in. All members of the household are deaf but the family compound is shared with hearing relatives who sign KK.

Data

Data for this study come from the Kata Kolok Child Signing Corpus (KKCSC) for which informed consent was obtained from the parents before the initial recording (de Vos, 2016; *Kata Kolok Child Signing Corpus*, 2021). The KKCSC comprises longitudinal video recordings of spontaneous interactions between focus children with their environment, including a large range of daily routines and conversational settings with hearing and deaf, and adult and peer interlocutors. Given the community structure, group-settings with mixed interlocutors are more common than one-to-one set-ups with only a primary caregiver.

For this study, we focus on early footage of four deaf children (SS, P3, CSA, CSC). Circumstances of recordings vary from child to child. SS and P3 were initially recorded in 2007 by a hearing research assistant who is a fluent adult signer and member of the village's Deaf Alliance (Marsaja, 2008). Recordings of CSA and CSC began in 2014 and 2017 respectively and were administered by deaf relatives of the focus children (DD and P2, Figure 2). Recordings differ in duration and density: SS and P3 were videotaped monthly for 30-60 minutes while CSA and CSC were videotaped for 4-5 hours each month. Here, we focus on the available data between the ages 1;3 and 3;1 years, amounting to 95h24min of data (SS: 13h45min; P3: 15h44min; CSA: 19h38min; CSC: 52h01min; Figure 3)[7].

[7]SS and P3 sometimes feature in the same recordings: these recordings are counted as individual footage for each child but counted only once for the total sum of data.

Coding and data preparation

All data were annotated using ELAN (*ELAN [Computer Software]*, 2020). Annotations were made by the first author, who acquired language fluency through extensive fieldwork since 2015, and checked with deaf research assistants and deaf family members of the focus children during fieldtrips in 2018 and 2019. Following a baseline coding of communicative interactions (on accelerated speed), we identified and glossed child modifications, i.e., signs that deviate from an adult target, as CV:GLOSS where CV flags the child modification (Child Variant) and GLOSS references the target sign. Unclear tokens were checked and discussed with deaf research assistants, and we excluded signs if i) they could not be identified during reviewing the data with a adult native KK signer, ii) they led to disagreement between research assistants and/or the first author, or iii) an accurate phonological transcription was impossible, e.g., due to difficult light conditions, low video quality, or the position of the focus child. In some instances, children produced bursts of strings of signs over multiple minutes, often with culturally relevant content such as EAT NOT-YET/FINISH or BATHE NOT-YET/FINISH. For the purpose of this study, each instance of a modified production in these bursts was included. The final count of child modifications was 1,246 tokens.

Signs glossed as CV:GLOSS were reviewed to add a feature-based form description. Our coding scheme is a simplified version of that used for Global Signbank, a lexical database with phonetic description (consult Crasborn et al., 2018 for details concerning features and available feature values) that codes for 19 properties. Of these, we selected ten fields: 'handshape dominant hand', 'handshape non-dominant hand', 'handshape change', 'location', 'movement shape', 'movement direction', 'contact type', 'palm orientation (absolute orientation)', 'orientation change', and 'non-manuals'. In addition, we coded for 'contact location' (see Appendix C for detailed coding scheme). Note that in Global Signbank, handshapes are not decomposed in sub-features, such as 'finger selection' or 'aperture' but coded holistically (as a cluster of features represented by a specific handshape). However, the coding of sub-components of 'handshape' is available through Global Signbank (see https://signbank.cls.ru.nl/handshapes/show_all/) and therefore, both types of representations are included in the analyses of this study. Each property was coded on an independent tier with a semi-colon separating different pieces of information, e.g., 'movement shape'; 'movement direction'. The pre-existing values for each feature in Global Signbank had to be extended occasionally given that child signing may take different forms than adult signing. Absence of a feature received NA coding, i.e., productions without 'handshape change' were coded as the value *NA* for this feature. Data were extracted per tier using the multi-layered search function in ELAN with regular expressions (CV:* in tier type Glosses overlapping with .* in the same file in each of the coded tiers).

Analyses

In order to bridge the discrepancies between the literature on sign phonology and studies on the acquisition of sign phonology, we combine qualitative and quantitative analyses. First, we report results from the feature analysis as rate and type of feature modification for each coded feature individually. Here, we present results on 'handshape' holistically in addition to providing an overview of an analysis of handshape features ('finger selection', 'finger configuration, 'unselected fingers', 'spreading', 'aperture'). Second, we provide a case study of movement in order to demonstrate differences between a feature and a

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parameter analysis. Third, we present a sign-level analysis in which we examine co-occurrence of feature modifications. Given that individual variation is commonly high across children (Fikkert & Altvater-Mackensen, 2013; Kidd & Donnelly, 2020), and our data include longitudinal data from four children at different ages, we first report results pooled across all children and then discuss child-specific patterns.

Feature analysis

We re-used the coding of adult target signs from the KK dataset in Global Signbank (Lutzenberger, 2020). Feature descriptions of all documented signs were exported and automatically matched to glosses in our dataset. We performed an automated comparison between the relevant features of target signs and child productions in order to i) determine whether or not individual feature values matched the target, i.e., localise modifications, and ii) classify the modifications as substitution, omission, or addition.

Sign-level analysis

This analysis extends the results from the automated comparison used in the *feature analysis* by exploring all modifications in each child variant rather than examining features in isolation. Instead of grouping by coded feature, we locate and then list **all** the feature value mismatches between adult and child production. We report two measures: i) the number of sign-level feature deviations, and ii) the frequency of deviations of specific feature combinations. In addition, we provide a qualitative discussion of multiple feature deviations using selected examples. First, we summarise what multiple feature deviations look like and second, we present a case study of modifications of EAT and MONEY to touch upon systematicity in the modification of certain feature values.

Results

Descriptive results

The data yielded 1,246 child modification tokens of 181 unique sign types. Proportional to the amount of available data, most instances stem from the youngest participant in the sample, CSC (Figure 4). Among the 181 types, EAT (*n*=113), MONEY (*n*=50), FINISH (*n*=45), and BAD-SMELL (*n*=42) are most frequent, accounting for 20% of the data. Find an overview of child modifications per minute of recording in Appendix D.

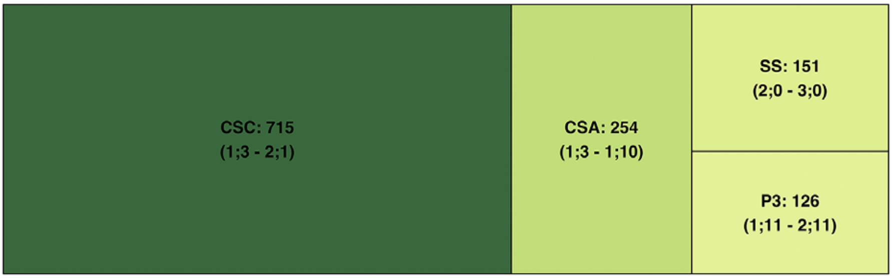

Figure 4. Number of modification tokens per child.

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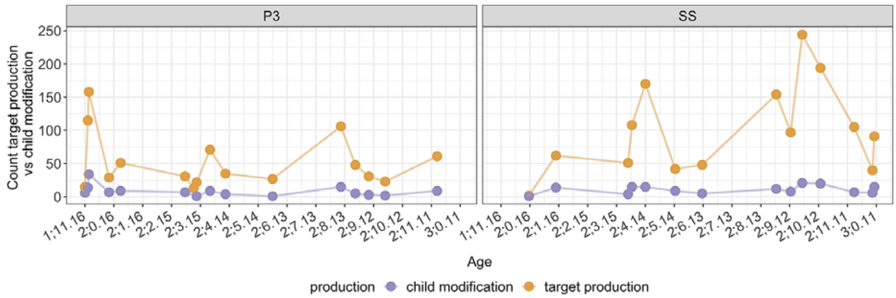

Figure 5. Number of child modifications and target (= adult-like) productions of two children of the sample (P3 and SS) over the course of the data in the dataset; annotations of target productions are not available at this moment for the data from the other two children (CSA and CSC).

Figure 5 shows child modifications in the context of two of the four focus children's (SS and P3) overall productions over time. This figure reveals two major observations: i) both children produce more signs on target than modifications, and ii) modifications persist through all ages. At the same time, the rate of modifications does not decrease steadily over time but seems to fluctuate depending on the recording session. The children continued to modify signs throughout the recording period (1;11-3;0 years).

For 127 tokens of 19 types, no unambiguous target sign could be identified (CSA: *n*=10; CSC: *n*=83; P3: *n*=13; SS: *n*=21); the KK dataset in Global Signbank currently registers around 1,300 entries [Signbank sample date: July 2021] including multiple variants that could function as target sign. As multiple possible target variants obscure the comparison, these instances are excluded from the results reported here and will be discussed later. The final number of tokens in the analyses is 1,119.

Feature analysis

In the following, we report the results of the feature analysis. The automated comparison of child modifications and adult targets yields modification rates per feature (Figure 6) and per modification type (substitution, omission, addition; Table 2). Modification rates are calculated per feature based on the number of modified feature values out of the total number of signs. Note that the extent to which these results can be compared to previous results in the literature is limited given methodological differences in data collection, data transcription and data analysis. For this reason, this section includes general statements about 'handshape' and 'location' and of how our results are contextualised in the literature.

In line with previous studies, most modifications concern 'handshape': 71.9% (804/1119) of the sample vary in 'handshape dominant hand' and 29% (324/1119) in 'handshape non-dominant hand' (Figure 6B). Specifically, children most commonly modify the 'selected fingers' (578/1119), 'finger configuration' (577/1119) and 'spreading' (540/1119). In our data, modifications in 'handshape' (holistically) are most commonly substitutions, although in the non-dominant hand additions or omissions sometimes occur as well. Different handshape sub-components show different modification rates – however, substitutions and omissions are most common across all 'handshape' features (Table 2). Omitting or adding a second hand has been previously reported in other studies

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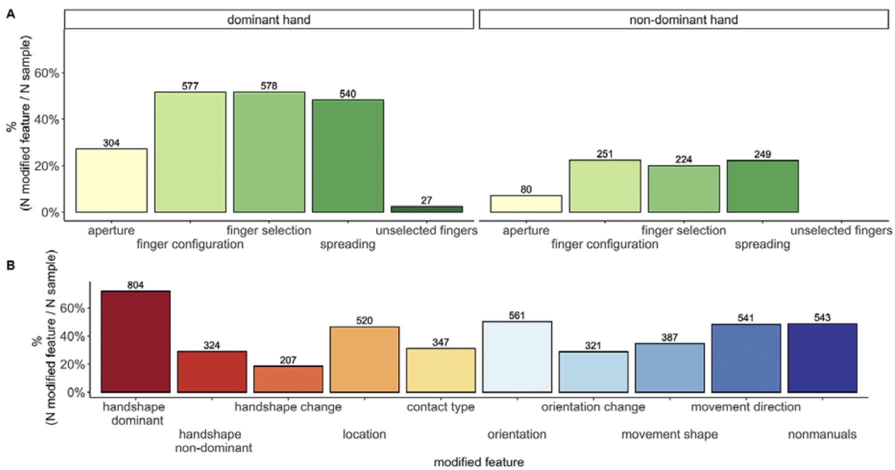

Figure 6. Rate of modification per coded feature, calculated as the ratio of the number of instances where the feature was modified and total number of signs in the dataset. A) shows modifications of features related to handshape (for dominant hand and non-dominant hand). Note that the denominator is the total number of signs in the dataset and therefore modification rates in the dominant and non-dominant hand cannot be compared directly since only a subset of signs have a phonologically specified non-dominant hand but all signs involve the dominant hand. This additional information is provided in Table 2. B) shows modifications for handshapes coded holistically and all other coded features.

(e.g., Marentette & Mayberry, 2000; Pichler, 2012) and is also frequent in spontaneous discourse among adult signers (e.g., Kimmelman, Sáfár & Crasborn, 2016).

Modifications in 'handshape change' occurred in 18.5% (207/1119) of the data. This may be related to the low rate of signs featuring a 'handshape change' in the lexicon; at present, 16% (209/1305 [Signbank sample date: Oct 2020]) of the signs documented in Global Signbank include a handshape change. Children attempted 23 sign types with 'handshape change' (12;7%; 23/181). Signs with handshape changes may thus be slightly underrepresented in our data. Although this could point towards avoidance strategies, it could also be linked to lexical frequency effects in the input. Rather than substituting the value, children tend to add a handshape change where there was none in the target, or omit handshape changes that are present in the adult target in their productions (Table 2). This may indicate that handshape changes may at times be difficult and therefore omitted, and at times added for ease of articulation. This can be due to the complexity of the feature value, due to coordinating the interplay of features (and feature values) on the sign level, and/or due to the mental representations that may not yet include adult-like contours.

Modifications of 'location' occur in 46.5% (520/1119) of our data, and this appears relatively more frequent in this dataset than in previous studies (e.g., Conlin et al., 2000; Morgan et al., 2007). One explanation for this difference may lay in our coding; we did not distinguish between major body location and exact location as some previous studies do (e.g., Marentette & Mayberry, 2000), and always coded the exact location of the hand(s). Moreover, the signing space in KK differs from other studied sign languages; in particular, KK signs make more frequent use of 'unusual' locations such as the *hip* or the *teeth* than other sign languages (Lutzenberger, Crasborn, Fikkert & de Vos, in in prep.; Marsaja, 2008). This typological difference is thus another possible source of heightened 'location' modifications in children acquiring KK. Whether these 'unusual' locations are indeed

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Table 2. Type of modification per coded feature within the sample of 1,119 signs.

Feature	Addition	Omission	Substitution	Total feature modified	Total feature attested target
Handshape dominant hand	N/A	11	793	804	**1119**
Handshape non-dominant hand	37	109	178	324	**382**
Finger selection dominant hand	84	152	342	578	**907**
Finger selection non-dominant hand	34	139	51	224	**321**
Finger configuration dominant hand	14	118	445	577	**1103**
Finger configuration non-dominant hand	39	134	78	251	**378**
Unselected fingers dominant hand	25	2	0	27	**2**
Unselected fingers non-dominant hand	0	0	0	0	**0**
Spreading dominant hand	156	198	186	540	**638**
Spreading non-dominant hand	41	144	64	249	**288**
Aperture dominant hand	72	204	28	304	**402**
Aperture non-dominant hand	26	54	0	80	**66**
Handshape change	108	75	24	207	**110**
Location	9	12	499	520	**1110**
Movement shape	109	183	95	387	**725**
Movement direction	101	188	252	541	**738**
Orientation	49	11	501	561	**1070**
Orientation change	76	153	92	321	**277**
Contact type	122	67	158	347	**690**
Non-manuals	46	389	108	543	**542**

more difficult to acquire should be investigated in a future study. Further, modifications in 'location' are overwhelmingly substitutions. This is unsurprising given that each sign involving manual activity, by necessity, needs to be articulated somewhere. Additions of 'location' are only possible when the child i) changes location values over the course of the sign or ii) adds a second hand at a different location (i.e., with a different location value), and omissions can only occur when the child omits the manual component altogether.

In our data, children modify 'movement direction' in 48.4% (541/1119) and 'movement shape' in 34.6% (387/1119) of the data. 'Movement shape' is most commonly omitted and added in nearly a quarter of cases while 'movement direction' is most often substituted. Due to the theoretical and methodological differences in this study (i.e., parameter vs. feature analysis), the rate of movement modifications cannot be compared straightforwardly to previous studies. Differences are exemplified in the Section Case study: movement.

We find frequent modifications in 'orientation' – namely, in 50.1% (561/1119) of tokens. Modifications were overwhelmingly substitution. This to be expected as additions of an orientation feature are only possible when a second hand is added, and omissions are only possible when the hand is dropped altogether.

Similar to 'handshape change', 28.7% (321/1119) of the tokens modified 'orientation change'. This sample includes 42 sign types (23.2%; 42/181) with 'orientation change' in the adult target. Global Signbank registers values for 'orientation change' in 20.3% (265/1305 [Signbank sample date: Oct 2020]) of entries, suggesting slight over-representation of this type of signs in our dataset. As for the type of modification, orientation changes are most frequently omitted although additions and substitutions sometimes occur as well.

We also examined modifications in 'contact type' and 'non-manuals', features that have previously not been explored in detail. Child-introduced modifications in 'contact type' values occur in 31% (347/1119) of the sample, most commonly as additions or substitutions (35.2%; 122/347). Furthermore, the number of modifications in non-manual aspects of the sign is relatively high (48.5%; 543/1119).[8] In many cases, children appear to omit the value present in the adult target and, in some cases, children add a value, possibly to approximate any omitted movement features. We will elaborate on this observation in the *Discussion*. Nevertheless, light conditions or position of the child's face may not always be ideal to judge whether or not non-manual elements are added, omitted, or modified, and, more crucially, we lack systematic investigations into non-manual features of signs other than 'mouthings' across sign language lexicons.

Individual differences across children

Despite the different ages, all focus children show similarity as to the rates of modification (Figure 7).

Children exhibit similarly high patterns of modifying 'handshape', 'location', and 'orientation'. Handshape modifications in the dominant hand range from 59.8% (152/254; CSA) to 71.4% (90/126; P3) and in the non-dominant hand from 20.5% (31/151; SS) to 42% (53/126; P3) of the sample (calculated based on total number of modification tokens produced by a given child). More specifically, 'handshape' modifications are most commonly due to changes in 'finger selection', 'finger configuration' and 'spreading' of the dominant hand; modifications in 'finger selection' occurred in 34.3% (87/254; CSA) to 50.5% (361/715; CSC), in 'finger configuration' between 40.2% (102/254; CSA) and 55.6% (70/126; P3) and 'spreading' in 36.6% (93/254; CSA) to 50.8% (64/126; P3). Modifications in 'location' occurred between 32.5% (41/126; P3) and 44.1% (112/254; CSA) and modification in 'orientation' between 43.7% (55/126; SS) and 59.8% (152/254; CSA). The ubiquity of modifications in features linked to 'handshape' may be related to the complexity of this set of features (see *Background*). It is however unclear why children of different ages show similarly high rates of presumably easier aspects, particularly 'location'.

Further, it remains opaque whether differences across children are driven by age or individual differences. Data from CSC and CSA cover earlier ages than data from SS and P3 (Figure 3) and, thus, higher modification rates are expected for CSC and CSA (at least in particular features). Some results follow these expectations: CSC and CSA yield higher modification rates for 'orientation change', 'handshape change', and 'movement

[8]Note that in many cases, non-manuals are likely to represent a set of features in languages like KK. However, modification patterns of the non-manual node will have to be fleshed out further in the future on the basis of a larger view of the lexicon.

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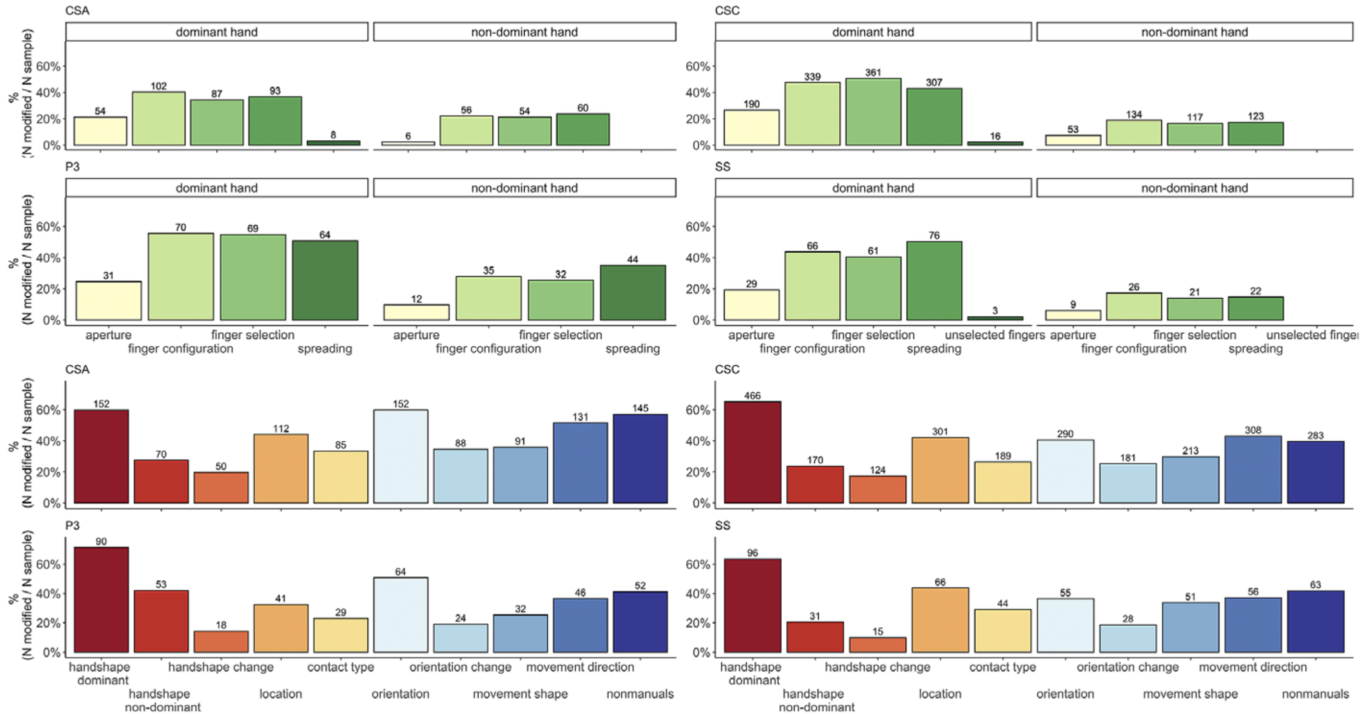

Figure 7. Individual differences in feature modifications, calculated as the ratio of the number of instances where the feature was modified and total number of signs in the dataset.

direction' than SS and P3. This may be related to maturing skills, and to the modification of different movement features (see *Case study*: movement). Nevertheless, we do not find considerably lower rates of modifications in 'handshape' in the older children. The rate of 'orientation' modifications further challenges age-related explanations; they are highest for CSA and P3, two children of different ages. This suggests explanations beyond age – for example, feature environment (sign complexity) and input effects.[9]

Last, some differences appear idiosyncratic. P3 modifies 'handshape' of the dominant and non-dominant hand more and 'location' slightly less often than the other children; SS modifies 'handshape non-dominant hand' and 'handshape changes' the least; CSA modifies 'movement direction' and 'non-manuals' the most. Whether these observations are linked to specific sign types remains to be investigated.

Case study: movement

This section illustrates fundamental differences between the current analysis and previous studies and demonstrates how to translate parameter results into the feature analysis of this study. Parameter approaches generally collapse different dimensions they might have coded for into the three major parameters handshape, location, and movement when reporting findings while feature approaches keep them separate. For example, movement is often separated out in path movement (conflating 'movement direction' and 'movement shape') and hand-internal movement ('handshape change' and in some studies also 'orientation change'). Table 3 provides a summary of selected recent studies as compared to the approach of the current study. While all studies in Table 3 code for multiple dimensions, they contextualise their findings on the level of parameters. As differences between the two approaches surface most strikingly in movement, we focus on this dimension and discuss selected examples here below.

Modifications can concern simple substitutions where a feature value is replaced by another one. A modification of this type is shown in Figure 8 with the sign BATHE produced by CSA at age 1;7 years. The adult target is articulated with a *B* handshape at the *chest* moving *straight up and down.*[10] CSA produces the sign with a *B* handshape that is located at the *chest.* Different from the adult target, the child moves her hand from side to side (*ipsilateral/contralateral*) rather than *up and down.* This modification is analysed identically as substitution of a single feature value in both approaches but reported as movement modification in a parameter approach and as modification in 'movement direction' in the present study.[11]

Modifications may concern changes of values across multiple features (Figure 9). The sign PAPAYA is produced by repeatedly moving the hand (*C_spread*) from the *mouth straight downwards* (palm facing the signer) while *protruding the tongue* (Figure 9A). At age 1;6 years, CSC produces a *B* handshape and *flexes* the wrist instead moving it *straight*

[9]As remarked by an anonymous reviewer, we would like to point out that the acquisition of handshape is a lengthy process and not expected to be completed by age 3;0 years old; nevertheless, our data do not show marked differences in modification rates between older and younger children.

[10]Note that it is at this point unclear whether thumb extension is contrastive in KK. Further, preliminary evidence from a small scale perception study demonstrates that more information is needed to determine whether *spreading* is contrasting the handshapes *B* and *5* (Lutzenberger, 2022).

[11]As pointed out by an anonymous reviewer, parameter-based studies include a wide range of different methods that differ in the degree of granularity of coding and analysis. Some have also described modifications of specific movement features, e.g., Siedlecki and Bonvillian (1993).

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Table 3. Comparison of selected parameter and feature approaches from the literature.

Coding Signbank	Present study	Conlin et al. (2000)	Karnopp (2002, 2008)	Morgan (2006)	Marentette & Mayberry (2000)
Handshape dominant hand	handshape dominant hand	handshape	subcomponents handshape	handshape	handshape right
Handshape non-dominant hand	handshape non-dominant hand	handshape	subcomponents handshape	handshape	handshape left
Relation between articulators	–	–	–	–	–
Handshape change	handshape change	–	hand-internal movement	–	hand-internal movement
Location	location	location	major location	location	vertical place of articulation
			exact location		horizontal place of articulation
Orientation: location	orientation palm	–	(unclear)	–	orientation palm
Orientation: movement		–	(unclear)	–	–
Orientation change	orientation change	–	hand-internal movement	–	hand-internal movement
Contact type	contact type	–	–	–	–
	contact location			–	contact location
Movement direction	movement direction	path movement	–	movement	–
Movement shape	movement shape	path movement	movement	movement	path movement
Phonology other	–	–	–	–	–
Mouth gesture	nonmanuals	–	–	–	–
Mouthing		–	–	–	–
Repeated movement	–	movement	–	movement	–
Alternating movement	–	–	–	–	–

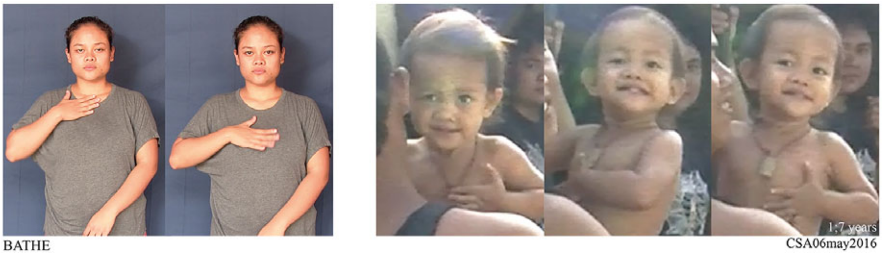

Figure 8. BATHE. Adult target and child production at age 1;7 years.

Figure 9. PAPAYA and FRY. Adult target and child production at age 1;6 years.

downwards. Similarly, the adult target FRY (Figure 9B) is a two-handed sign where both hands have *B* handshapes and are positioned perpendicular to each other; the dominant hand moves forwards and backwards through wrist *extension and flexion*, i.e., an 'orientation change'. CSC's production at age 1;6 years is initiated with a single *flexion* of the wrist and adds a *straight downwards* movement of the dominant hand to touch the palm of the non-dominant hand. Both examples in Figure 9 are classified as substitution in a parameter analysis; one type of movement is substituted for another one. Our feature analysis is more nuanced: rather than a substitution both examples combine a deletion and an addition. In the case of PAPAYA (Figure 9A), CSC deletes the target value of 'movement shape' (*straight*) and 'movement direction' (*downwards*) and introduces an 'orientation change' (*flexion*). In FRY (Figure 9B), CSC adds a value in 'movement direction' (*downwards*) and in 'movement shape' (*straight*) alongside deleting the target value of 'orientation change' (*flexion;* after an initial iteration). These examples demonstrate that modifications of this type are insufficiently described as substitutions which is why previous studies that code joint involvement have identified proximalisation and

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distalisation as characteristics of child signing. We argue that in addition to coding joint involvement (which is rarely ever done for adults; see Crasborn, 2001 for discussion), these examples are better understood as complex arrays of deletion and/or addition of a particular (set of) feature(s) (values) than as movement substitution.

Sign-level analysis

Until here, we reported feature modifications in isolation. We now turn to the sign-level analysis. We first report the number of features that are modified at the same time, and then frequent combinations of modified features. We then turn to the qualitative analysis where an exemplar sign-level analysis of the signs EAT and MONEY provide insights into whether there is systematicity in what feature values are modified together. Non-manuals are not included in the results reported here since we lack insights into variation across adult KK signers and an adequate coding scheme.

Within a single sign, modifications of more than one feature value are the norm (Table 4; mean=3.59; SD=1.77; range=1-8). Signs with modifications in a single feature value only account for 13.4% (150/1119) of the sample. Children most frequently modify three (22.2%; 249/1119), four (17%; 190/1119), or two (16.4%; 184/1119) feature values at the same time. Comparing the numbers for each child, CSA (mean = 3.82; SD = 1.77; range =1-8), P3 (mean = 3.51; SD = 1.59; range =1-7) and CSC (mean = 3.55; SD = 1.81; range =1-8) most frequently modify three and SS (mean = 3.4; SD = 1.66; range =1-7) two feature values within a sign. Clearly, analysing child signing in terms of features in isolation fails to capture the full complexity of child modifications.

Examining the modifications on the sign level reveals that the same features that showed the highest modification rates in the feature analysis are also the most frequent on the sign level; specifically, 'handshape', 'location', and 'orientation' are often the sole modification in a sign and frequently modified in combination with other feature values. Modifications of 'handshape' values are striking; they occur in 13 out of the 16 most frequent patterns in Figure 10. Besides modifying only the value of 'handshape dominant hand' (92/1119), 'handshape dominant hand' values are very often modified alongside 'location' values (40/1119), or even in the combination 'handshape dominant hand', 'location', and 'orientation' (32/1119) (Figure 10). Quantitatively, modifications of

Table 4. Overview of number of modified features/feature values within a sign.

N of deviating features	CSA	CSC	P3	SS	Total
1	18	103	14	15	**150**
2	37	100	15	32	**184**
3	69	120	34	26	**249**
4	44	108	17	21	**190**
5	32	102	17	21	**172**
6	21	63	14	9	**107**
7	14	26	2	6	**48**
8	9	10	0	0	**19**
Total	**244**	**632**	**113**	**130**	**1119**

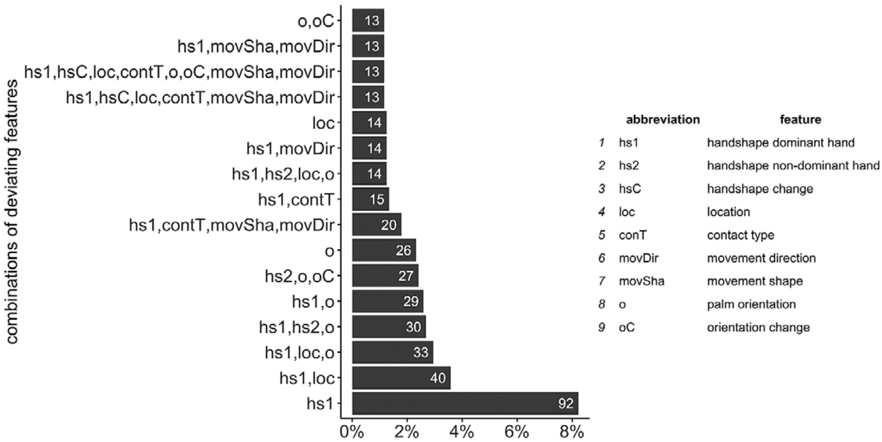

Figure 10. Overview of most frequent sign-level modifications. In order to increase readability, this figure summarises the combinations of modified features that are attested in more than 1% of the data (full graph in Appendix E).

Figure 11. COFFEE. Adult target and child production at age 2;3 years.

'handshape' play a crucial role in child signing, both as the only modified feature as well as co-occurring with other modifications.

Qualitatively, these data may suggest that the sign-level environment of features influences child modifications. Consider two examples of the two most frequent types of modifications concerning multiple feature values: i) 'handshape' (dominant hand) and 'location' (Figure 11), ii) and 'handshape' alongside 'location' and 'orientation' (Figure 12).

CSC's production of COFFEE at age 2;3 years differs from the adult target in 'handshape' and 'location' values (Figure 11). Adult signers articulate COFFEE by placing the *1* handshape at the *temple* and executing a repeated twisting movement ('orientation change'). Attested variation among adult KK signers concerns 'handshape' (*1* vs. *1_curved*; *extended* vs. *curved* index finger) and 'orientation change' (*pronation* vs. *supination*) (Lutzenberger, 2020). CSC's production involves *repeated supination* with *lax extended* fingers where the middle finger contacts the *ear*. While CSC's production aligns with the adult target with respect to 'orientation' and 'orientation change', her

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Figure 12. FATHER. Adult target and child production at age 1;6 years.

'handshape' value differs from both attested variants used by adult signers in terms of 'selected fingers': CSC has *all* fingers extended in a lax manner and bends the *middle finger* whereas adult variants select the *index finger*. CSC's production also differs in 'location' values; the *ear* in CSC's sign is lower and more peripheral than the canonical target 'location' *temple* used by adult KK signers. Although it has been previously suggested that children modify locations to aim for bigger and more salient locations (Marentette & Mayberry, 2000), it is unclear whether this explains the current modification; the (inside of the) *ear* and the *temple* are similarly sized and there is no obvious increase in salience for this particular sign. As suggested by an anonymous reviewer, there may be a tactile advantage for the *ear* 'location' as compared to the *temple.* Moreover, lowering of sign locations has been attested in discourse across adult signers of different sign languages (Mauk & Tyrone, 2008; Russell, Wilkinson & Janzen, 2011). It is thus possible that these modifications are triggered by the sign-level feature environment, i.e., coordinating multiple feature values at the same time. However, there is also some similarity to child modifications reported for other sign languages: Conlin and colleagues (2000, p. 59) report that their deaf participant Susie substituted *upper lip* with *nose* in the ASL sign DOLL at the ages 1;2 and 1;3 years and *upper lip* with *ear* in the ASL sign FLOWER at age 1;2 years and Looney and Meier (2014) report that their participant Genie (Curtiss, 2014) shows a preference for middle finger contact over index finger contact, similar to the reported production of COFFEE.

In Figure 12, CSC modifies 'handshape', 'location', and 'orientation' values of the sign FATHER. Adults produce this sign by placing the *1_curved* handshape above the *top lip*, radial side of the index finger making *continuous* contact with the face, *palm facing downwards.* At age 1;6 years, CSC places the *1* handshape at a lower location – the *mouth* – and modifies the 'palm orientation' value from *downwards* to *forwards.* All values of movement features match the target; neither the adult target nor the child sign involve movement components. A crucial aspect of this child production is that all the modifications result in an increased contact area, radial side of *curved index* above *top lip* as compared to the back of *extended index* and hand on *lips.* It is possible that modifications are in part driven by aiming for an increase or addition of body contact which may be used for proprioceptive feedback and is also highly prevalent in child-directed signing (Holzrichter & Meier, 2000; Pizer et al., 2011).

More specifically, taking the tokens of the target signs EAT and MONEY as examples suggests that there may be concrete modification patterns underlying child modifications that may generalise more broadly across different features and feature values or indicate strong individual variation.

In 24 out of 113 tokens of EAT, multiple feature values are modified. Attested modifications include changing the values of 'contact type', 'movement shape', 'movement direction', and/or 'location. Most frequently, children change 'contact type' alongside 'movement shape' and 'movement direction' (*n*=16) through a combination of omitting both features and adding *continuous* contact. This is very frequent across modifications of EAT (CSC: *n*=10, CSA: *n*=5, SS: *n*=1), sometimes also combined with an additional 'location' modification to *inside the mouth* or more peripherally at *cheek* or *chin*. These modification patterns highlight the importance of i) analysing modifications on the sign level and ii) the dependency of features; omitting 'movement shape' and 'movement direction' limits possible contact values to *none* or *continuous* (or the other way round, changing the contact value to *continuous* will affect movement features). It is at this point unclear what the driving factor for these modifications is.

In all 50 tokens of MONEY, multiple feature values are modified. All instances include modifications in at least one 'handshape', most frequently in 'handshape dominant hand', 'handshape non-dominant hand' and 'orientation' (*n*=20), or 'handshape non-dominant hand', 'orientation' and 'movement direction' (*n*=11). When modifications in 'handshape dominant hand', 'handshape non-dominant hand', and 'orientation' co-occur, both handshapes change into *5* handshapes, i.e., selecting *all* rather than no fingers in 'handshape dominant hand' and adding *spread* to 'handshape non-dominant hand', and the palm is turned to face *inwards* (contralaterally) rather than *backwards* (towards signer) (*n*=10). All of these instances stem from P3. The remaining tokens include variation in 'handshape dominant hand' or 'handshape non-dominant hand' values (*5*, *A*, *baby_Beak*, *beak*) and consistent modification of the 'orientation' value to *inwards*. When modifications in 'handshape non-dominant hand', 'orientation' and 'movement direction' co-occur, children change the target *B* handshape into a *S* handshape (i.e., change 'selected fingers' from *none* or *all*), the target 'orientation' palm *backwards* to *inwards* (contralaterally), the target 'movement direction' from *contralateral* to *ipsilateral* (*n*=10). Note that all of these instances stem from CSA. In short, children produced a symmetric sign in which two identical handshapes move towards each other with palms facing each other; feature values that differed between the two hands were assimilated to mirror each other.

Examples in Figure 11 and Figure 12 show child productions that are perceptually fairly similar to the adult target. Nevertheless, the child modifications go beyond the variation attested in adult signers and concern multiple features. Modifications in multiple features are frequent, suggesting some regularities in child modifications, both in terms of what features are often modified at the same time as well as whether there are frequent modification patterns of feature values. Although further exploration is needed, feature modifications may result from the need to coordinate different features within a sign, and/or the reliance on specific features, e.g., exploiting contact for proprioception.

Discussion

This study is the first to analyse child modifications using the same feature approach as used for coding their adult models and to add a rural sign language to the languages studied for acquisition of phonology. We collected child forms from longitudinal data of

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four deaf children aged 1;3 to 3;1 years who acquire KK as L1 and automatically compared child modifications to adult target signs from the lexical database Global Signbank on the basis of ten form features. This study resulted in three main findings: i) modifications in 'handshape' values are the most frequent across the sample, echoing cross-linguistic findings; ii) conversely, modification rates of other features differ from previous studies, which may be due to methodological discrepancies and/or to KK's phonology; iii) many child modifications are complex compositions of modifying multiple feature values simultaneously on the sign level, situating modifications of feature (values) within their broader linguistic context. While there are great methodological differences with previous studies, in terms of theoretical approach, coding scheme and analysis, we believe that our study advances the field with at least three novel contributions: i) insights into the acquisition of an understudied language; ii) direct comparison using the same (feature) coding across adult and child data; iii) sign-level analysis that acknowledges that children commonly modify multiple aspects of a sign at the same time. Taken together, this study increases the ecological validity of studying child modifications.

Typology of developmental sign phonology

Previous studies have consistently found the highest rate of modification to be in 'handshape', followed by 'movement' and the least modifications in 'location'. Despite differences in methodology, this study suggests that this might not be the case for KK: most modifications occur in 'handshape' (most commonly 'finger selection', followed by 'finger configuration' and 'spreading'), followed by 'orientation' and 'location' and features coding for different movement aspects show different modification rates. In the following, we discuss how our three main findings fit into the typology of the acquisition of sign phonology.

Models of sign phonology suggest featural hierarchies and interdependencies (Brentari, 1998; Sandler, 1989; van der Kooij, 2002). We argue that modification rates in child signing may be linked to the inherent nature of the different features and their interdependencies. In other words, frequency of a feature and its inventory size are likely to predict the rate of modification. First, features differ in their absolute frequencies since features related to 'handshape', 'location', and 'orientation' would code specific values in every possible sign but not all signs would code, for example, for different movement features (recall Table 1). Second, features differ in inventory size, i.e., the number of possible values. The physiology of the hand allows for independent manipulation of most finger and finger joints (however, see Ann, 1996 for a discussion of handshape frequency and articulatory ease), resulting in a larger range of possible values for handshape-related features than, for example, 'orientation'. Thus, features that are very frequent and features with larger value inventories are expected to show higher modification rates in children because more different values need to be learned. Although this study provides tentative evidence for this prediction, the exact inventory size is at this point unclear for KK. Third, feature dependencies may explain rate and type of child modifications. For example, 'orientation' is a result of specifications of 'handshape' and 'location' (Sandler, 1989), and, consequently, modifying 'handshape' or 'location' values may cause an 'orientation' modification as a by-product (or the other way round). As shown in Figure 10, children modify the target values in these three features often simultaneously. In adult signs, 'movement direction' and 'movement shape' always coincide, i.e., any sign that codes a non-NA value for 'movement direction' will also be specified for 'movement shape'. Yet, children modify the values of both features to different extents, i.e., seemingly independent of each other. Unlike the combination of 'handshape' and 'location' to result in 'orientation' there is no conditional relevance between 'movement shape' and 'movement direction'. This indicates that movement aspects may pose different challenges.

Taken these arguments together, high modification rates of 'handshape' are expected to be robust cross-linguistically. We propose that, in addition to that, the sign-level feature environment may play a crucial role in child modifications. It has previously been highlighted that children simplify handshapes by replacing complex, not-yet-acquired handshapes with easier ones that they have already acquired (Boyes-Braem, 1990). The sample in this study yielded 181 sign types, most of which are produced with a small range of easy handshapes. If indeed children consistently use easy handshapes, we would expect fewer 'handshape' modifications in this study than in other studies, or at least anticipate older children to show less modifications. This is not the case: we find high rates of 'handshape' modification across all children (Figure 7) and similar rates across children from generation V (2-3;1 years) and generation VI (1;3-2 years). This suggests that incomplete acquisition of individual handshape values as driven by age may not be the only explanation of this finding. The high modification rates may instead be related to the challenge of coordinating sign-level complexity (see *Sign-level analysis*), i.e., articulating a particular handshape alongside other feature values.

Our findings differ from previous studies especially in 'location', possibly due to methodological and/or typological reasons. 'Locations' are coded identically in parameter and feature approaches, unless further subdivision into major and exact location is coded, yet we find high rates of modifications in 'location' values. One of the typologically unusual characteristics of the KK lexicon is the use of an extended signing space and 'unusual' location values (de Vos, 2012a; Marsaja, 2008). It is possible that these factors affect the observed rate of modifications. KK differs from the sign languages studied for acquisition of sign phonology in many socio-demographic and linguistic aspects, and the first to show considerably higher rates of 'location' modifications. To further investigate how typological differences in sign phonologies influence acquisition patterns, a qualitative study of the exact forms and substitution patterns of particular feature values is needed.

Further, this study separates different types of movement based on their articulatory characteristics and finds different rates and types of modification for different movement-related features. Existing literature reports higher accuracy in path movement than in hand-internal movement, suggesting that hand-internal movement is more difficult for children (Cheek et al., 2001; Marentette & Mayberry, 2000; Morgan et al., 2007). This study finds that features that encode hand-internal movement equivalents (i.e., 'handshape change', 'orientation change') are not primarily avoided. To the contrary, values for 'handshape change' are mostly added where there was none present in the adult target and values for 'orientation change' are equally often added and substituted but omitted in half the cases (Table 2). One frequent pattern is the combination of omissions and additions of values such as in the case of FRY and PAPAYA in Figure 9 where the child omits the target values for 'movement shape' and 'movement direction' and adds a value for 'orientation change' that is not attested in adults (or the other way round). Another pattern is adding an extra feature value without

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Figure 13. NOT-YET and SIGN-NAME. Examples of handshape change additions in child productions.

omitting another one. For example, in addition to a wrist *flexion* ('orientation change'), CSC *flexes* her *curved* fingers at the base joint ('handshape change') in NOT-YET (Figure 13A) and introduces a *wiggle* of her extended index finger ('handshape change') in SIGN-NAME (Figure 13B). Although the 'handshape change' in NOT-YET could potentially be analysed as movement extension or articulatory by-product, the addition of an 'handshape change' in SIGN-NAME is unmotivated. This suggests that modifications in 'handshape changes' and 'orientation changes' may be used for ease of articulation on the sign level.

Limitations of this study

Naturally, there are limitations to this study, especially challenges related to limitations of available data and resources and to variation.

First, in this study, we focused on analysing modifications and provide limited insights into target productions of the children. This is due to restrictions in how much transcription is available for the collected data. As previously mentioned, the acquisition of KK is at this moment virtually unexplored and the KKCSC is a growing resource of primarily video data but lacks a high level of transcription. Having set the foundation with this study, a future study could investigate modifications and target productions, aiming at an extension of the sign-level analysis of this paper by drawing direct parallels to the adult and child targets produced around the same time.

Second, the considerable variation across adult signers in the community and particularities of a small dataset pose limitations to this study. This study defines child modifications as deviation from an adult target while adult KK signers show considerable variation both on the sign and the formational level (Lutzenberger, de Vos, Crasborn & Fikkert, 2021; Mudd et al., 2020). To deal with this, we relied heavily on our

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knowledge of the community and the language, discussions with the research assistants and Global Signbank to decide whether or not child productions are modifications. Cases with multiple possible adult targets due to cross-signer variation were excluded from the analysis (n=127). The village's community-oriented culture and living in intergenerational family compounds leads to interacting with many deaf and hearing interlocutors of different ages from early on and makes relying on only the parents' variant insufficient. Nevertheless, it is unclear how cross-signer variation impacts language input. One possibility to deal with multiple possible target signs is to use the variant that resembles the child variant the closest; another one is to determine the differences between adult variants and then locate overlap between multiple adult variants and the child production; yet another one is to compare the child production to all features of all variants. Although similar issues have also been raised in lexical comparison of sign languages (Börstell, Crasborn & Whynot, 2020), it remains unclear which procedure best addresses this issue.

Third, another complicating factor is that some signs may be idiosyncratic forms without any formal overlap between the child production and documented adult variants. For example, SS produces an exaggerated *blink* and *eyebrow raise* to refer to video camera. Multiple signs for camera are used by adult signers: all of them include manual components but no *blink* or *raised eyebrows.* Another example from CSC shows no form overlap with any adult variants: CSC bites her extended index finger (*1* handshape) to refer to ghost or spirit. Both the examples of SS and CSC may be child-specific or family-wide conventions (familylects). Such instances may resemble the role of onomatopoeia in the early acquisition of speech; despite high individual variation, onomatopoeia appear to aid word learning and are frequent in both early production and input (e.g., Laing, 2019; Motamedi et al., 2021). However, different from onomatopoeia and familylects, we did not observe any adult family members producing those signs spontaneously. While adults may copy CSC's variant or prompt her with it in child-directed signing, this is completely unattested with SS's variant. For this study, we analysed such signs as extreme modifications of an identifiable target, as confirmed by the research assistant or caregiver. Nevertheless, a follow-up study exploring child-specific conventions in more detail promises rich insights into the acquisition of phonology and characteristics of the child's language input.

Lastly, some child modifications are dynamic and may change within one token. The child modification of PAPAYA in Figure 9A starts at the *mouth*, lowering the hand to touch the extended *tongue*, i.e., 'location' changes from the target location to a different location. In other cases, children may start out with a modified value and finish their production matching the adult target. In this study, we have not considered the length of a child sign as modification nor have we paid particular attention to repetition. This is due to the fact that it is presently unclear what role repetition plays across adult KK signers, thus leaving it an impossible task to study how children deviate from adults. It is, however, possible that examples as detailed above are in line with observations made by Meier and colleagues (Meier, 2006; Meier et al., 2008) according to which children often increase the number of movement cycles to attain prolonged signs that may allow time for self-correction.

In sum, this study opens many possibilities for future studies on the acquisition of KK including but not limited to the analysis of the entirety of early signing (i.e., target productions and modifications) as well as the role of variation and iconicity in the input and early productions.

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Contact & non-manuals

Our data suggest that children frequently modify signs to include *continuous* contact; adding it where there was no contact before and substituting other 'contact types' for *continuous* contact. One reason why children may strive for increased contact is that it allows for tactile feedback. Similar to auditory and visual feedback that may facilitate the early acquisition of labials in speech-acquiring children (Boysson-Bardies & Vihman, 1991), tactile feedback may aid sign acquisition. Moreover, contact is frequent in child-directed signing as well; parents choose sign variants with contact over sign variants with handshape changes and often increase sensory feedback by producing signs on the child's body (Holzrichter & Meier, 2000; Pizer et al., 2011). Finally, increased contact and movement modifications are linked; omitting movement features often results in added or prolonged contact. It is possible that increased contact results from movement omissions or that the latter are caused by maximising contact. Nevertheless, contact has received relatively little attention in prior literature. Marentette and Mayberry (2000) note a preference for finger-tip contact; Conlin and colleagues (2000) report loss of contact in child signing; and Bonvillian and Siedlecki (1996, p. 31) describe perseverance of contact between hands, low omission, frequent addition, and high accuracy of contacting action even in early signing. Future work could explore how proprioception and input effects interact by examining how and where parents devise contact, how children maintain and enlarge contact, and how contact modifications coincide with modifications of other features.

Instead of a proprioceptive advantage for the learner, it is also possible that a preference for contact in child signers is related to KK's phonology. A study on name signs, a sub-group of signs attributed to individuals, compares KK to Sign Language of the Netherlands (NGT) and finds a tendency for *continuous* contact in KK but not in NGT regardless of the area where the sign is produced (Lutzenberger, 2018). Corroborating this with more data, the comparison between the NGT and the KK datasets in Global Signbank indicates that indeed the proportion of signs with 'contact' values in KK is higher than in NGT; from the documented signs, 47.7% (623/1305 [sample date: Oct 2020]) of the KK signs code a 'contact' value, compared to 36% (1491/4159; [sample date: Oct. 2020]) of the NGT signs. It is thus possible that proprioceptive advantages for (child) learners are enhanced by typological characteristics of KK. These two possibilities could be tested through intra- and cross-linguistic comparisons of the lexicon and the sample of child modifications. Cross-linguistic similarities in child modifications would point towards a proprioceptive advantage while intra-linguistic similarities between child modifications and lexicon may suggest an effect of divergent phonologies.

Another understudied domain highlighted by our study comprises non-manual modifications in child signing. Besides mouthings, non-manual elements have been largely neglected in the study of sign language phonology and, as a result, have been underexplored in their acquisition. Here, we highlight three types of modifications of 'non-manual' values that may open up future research avenues (Figure 14): i) omission of all manual aspects of a sign; ii) omission of all manual aspects of a sign with retaining only non-manuals; iii) omission of particular manual features to be replaced with non-manuals.

First, children may omit all manual aspects of the sign and instead, add a characteristic non-manual. Previously, such cases may have been analysed as imitations (e.g., Marentette & Mayberry, 2000), e.g., the sign WALK-AROUND is replaced with a bodily action of *bopping up and down* (CSA, 1;10 years). Second, children may omit all manual and retain only the non-manual component(s). Such cases may be analysed as extreme reduction that may sometimes also occur in adult signing (Dively, 2001). For example, DIE can be

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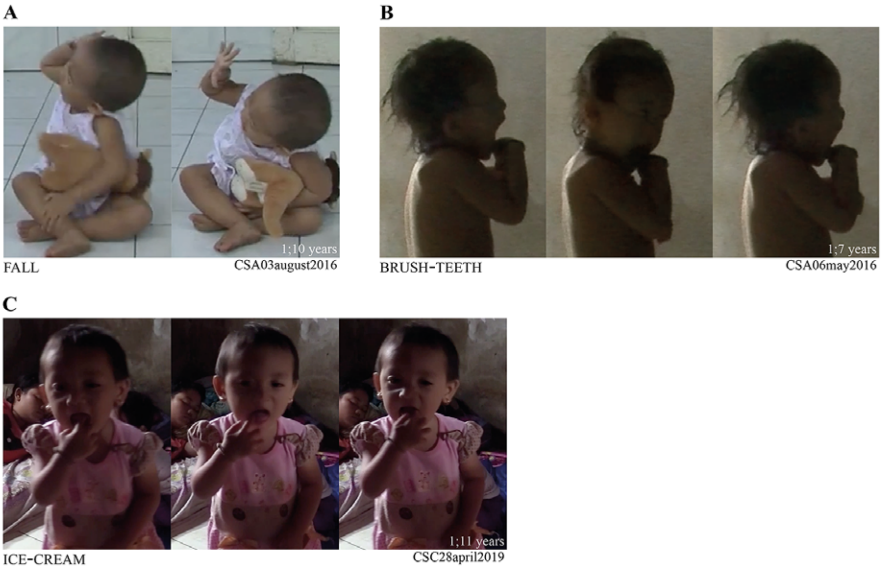

Figure 14. Child productions where non-manuals take over the movement component.

signed as the target non-manual *tongue protrusion* only (CSC, 1;7 years), or FRIGHTENED as a *full body shrug* (CSC, 2;0 years). Third, children may omit a particular feature value – primarily movement – and add non-manuals to replace it (Figure 14) (see Meier et al., 2008, p. 86 for a similar example from ASL). These cases may be examples of cross-feature substitution or extreme proximalisation that are particular to child signing. For example, adult signers produce FALL with *supination* and *arc* movement *downwards* with the *5* handshape while CSA (1;10 years) maintains a *5* handshape and bends her *body sidewards* (Figure 14A). In another example, CSA and CSC introduce a *headshake* to replace a sign's movement. In BRUSH-TEETH, CSA (1;7 years) keeps her hand still and moves her head from side to side where adult signers move the *1* handshape repeatedly from side to side (Figure 14B). In ICE-CREAM, CSC (1;11 years) shakes her head instead of moving her hand repeatedly downwards as in licking a popsicle (Figure 14C). These preliminary observations suggest that children recruit non-manuals to resemble the Gestalt of the adult target. A systematic study of acquiring non-manuals promises important insights into the patterns of child modifications, in particular in sign languages like KK where non-manuals may play a greater role than in sign languages used in urban contexts (Lutzenberger, 2018; Marsaja, 2008).

Conclusion

This study has addressed two aims: first, expanding the diversity of sign languages studied for acquisition both typologically and in terms of acquisition settings; second, working towards closing the gap between research on sign phonology and its acquisition through performing the same feature analysis on adult and child data. We have shown that a detailed feature and sign-level analysis may help unravel how children modify signs, accommodating both an analysis of feature modifications in isolation, and approaching

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child productions in their entire complexity. Hereby, this study paves the way for intra-linguistic comparisons between child modifications and adult target signs, as well as comparisons of child modifications across sign languages and even with the acquisition of spoken phonologies. Similarities between this study and the previous literature may suggest shared mechanisms in the acquisition of sign phonology; the high prevalence of modifications in 'handshape' values across all studies, for example, may be impacted by motor skill and cognitive development – and, as highlighted in this study, characteristics of the feature value inventory, the sign-level feature environment and possibly feature interdependencies. Cross-linguistic differences may be linked to typological differences in the linguistic structure, the acquisition setting and methodological differences. Although we do not believe that the differences found in this study are necessarily all KK-specific findings, possible comparisons are limited given the methodological differences. Future studies could aim at unifying methodological approaches, targeting more intra-language and cross-linguistic similarity when coding and analysing child modifications. Further, the popularity of using lexical databases for these analyses allows for robust intra-linguistic results. Analysing child modifications from other sign languages using the same feature approach as in this study may provide the chance to disentangle differing phonologies from more general differences brought about by the chosen methodology. Moreover, the present study is the first to explore child modifications on the sign level. Clearly, there is an urgent need to further explore combinations of modifying multiple feature values. More studies dedicated to sign-level modifications will be beneficial to identifying what aspects of child signing are indeed shared across sign languages and what aspects are language-specific. These cross-linguistic comparisons could then be further extended to cross-modal comparisons between the acquisition of phonology across both spoken and signed languages. Indeed, many of the methodological issues, the question as to the domain of analysis (i.e., feature-level vs. sign-level) and the role of feature-dependencies discussed in this study are challenges shared by studies investigating the acquisition of spoken language phonology. Cross-modal comparisons could provide an opportunity to refine methods and advance both fields.

Acknowledgements. We thank all Kata Kolok children and their families for their willingness to participate in the KKCSC and to be part of this research. We also thank our research assistants Ketut Kanta, Ni Made Dadi Astini and Ni Made Sumarni for their dedication and long-term collaboration. We are grateful to Rehana Omardeen and the Sign Language Linguistics group at Radboud University for comments on earlier drafts. This research was part of the doctoral project of Hannah Lutzenberger at Radboud University, supported by FWO-NWO under Grant [NWO 326-70-002] "The emergence of phonology within six generations" awarded to Bart de Boer, Paula Fikkert, and Connie de Vos. The research was further supported by NWO under Grant [VICI 277-70-014] "Deaf communication without a shared language" awarded to Onno Crasborn and under Grant [VENI 275-89-028] "The face in sign language interaction" awarded to Connie de Vos, and by the European Research Council Advanced Grant (ERC-ADG 885220 SignMorph) awarded to Adam Schembri. The handshape fonts are created by CSLDS, CUHK.

Supplementary Materials. To view supplementary material for this article, please visit http://doi.org/10.1017/S0305000922000745.

Competing interests. The authors declare none.

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Cite this article: Lutzenberger H., Fikkert P., De Vos C., & Crasborn O. (2023). Development of sign phonology in Kata Kolok. *Journal of Child Language* 1–34, https://doi.org/10.1017/S0305000922000745