The Form of Children’s Early Signs: Iconic or Motoric Determinants?

Richard P. Meier
Departments of Linguistics and Psychology, The University of Texas at Austin

Claude E. Mauk
Department of Linguistics, The University of Pittsburgh

Adrianne Cheek
Department of Linguistics, The University of Texas at Austin

Christopher J. Moreland
Plan II Honors Program, The University of Texas at Austin

The two major language modalities—the visual-gestural modality of sign and the oral-aural modality of speech—offer different resources to the infant word learner and impose differing constraints on the infant’s production of lexical items. For example, the attraction of iconicity to signing children could be such that their errors would reveal little role for biomechanical factors analogous to those that constrain early speech production. The earliest ASL signs of four deaf infants, aged 8 to 17 months, are examined. Three studies of a corpus of 632 early sign tokens are reported. The first study examined the effects of children’s errors on the iconicity of the target signs. Children’s signs were— with few exceptions—judged to be either as iconic (or noniconic) as the adult model or to be less iconic than the adult model. The second and third studies examined two independently-attested tendencies from general motor development: in many motor domains (including speech), infants exhibit repetitive movement patterns; infants may also proximalize movement vis-à-vis what would be expected from adults. Both tendencies are shown to predict error patterns found in the early sign data.
Children make errors in the production of their first words and in the production of their first signs as well. No surprise there. The interest in their errors—and in their early achievements—lies in the fact that patterns of success and failure may reveal the capacities and constraints that shape young children’s production of their earliest lexical items.

In important respects the structures of words and signs are similar. Signed and spoken languages exhibit duality of patterning, such that meaningful units are built of meaningless units of form. Just as words may differ in only one phoneme (e.g., *pat* and *bat*), signs may differ in just handshape or place of articulation or movement (Stokoe, 1960); thus the signs *apple* and *candy* in American Sign Language (ASL) differ only in handshape, whereas *summer*, *ugly*, and *dry* differ only in place of articulation.¹ Like spoken languages, signed languages differ in the inventories of meaningless gestural units out of which they form signs; for example, the extended middle finger is not a licit handshape in ASL, but is in several other languages (as in the sign *vacation* in Australian Sign Language: Johnston, 1998). Even when spoken languages share the same phonemes, they may have different linguistic constraints on their combination; the same happens in signed languages (see the comparison of ASL and Chinese Sign Language in Klima & Bellugi, 1979). Moreover, slips of the hand—like slips of the tongue—show that the mental representation of signs is not holistic. Instead, slips reveal the meaningless sublexical units that linguists posit within signs (Klima & Bellugi, 1979).

Notwithstanding these shared ways in which signs and words are structured, the visual-gestural and oral-aural modalities differ in the resources that they provide for signed and spoken vocabularies. One resource available to signed languages is the capacity for iconic representation in the visual-gestural modality. Here we explore the extent to which infant signers exploit this capacity in their production of signs. To understand why this may be revealing, consider what a word is. A linguistic symbol is a form-meaning pair (Saussure, 1916). In acquiring such a symbol—be it a word or a sign—children must learn three things: its form, the concept it signifies, and the mapping between form and concept. A child’s attempt to articulate a sign or word may be constrained by an imperfect phonological representation of the adult model (due, for example, to perceptual confusion) or by an immature articulatory system. In ASL and other signed languages, a child’s production could also be guided by iconicity; many—but by no means all—mappings between form and concept in ASL are motivated. Accordingly,

¹English labels for ASL signs are printed in small caps. Excellent illustrations of most signs mentioned in this paper are found in Humphries, Padden, and O’Rourke (1980). When describing the form of signs, we will often use labels for handshapes (e.g., an “S-hand” or a “5-hand”) that are based on the handshape’s value in the ASL fingerspelling or number name system. An online ASL dictionary is: http://commtechlab.msu.edu/Sites/aslweb/browser.htm
some signs seem to resemble what they mean. Thus, the usually one-handed sign CAT sketches the whiskers of a cat; production of this sign entails the repeated movement of the dominant hand away from the signer’s cheek. Inasmuch as the animal has whiskers on both cheeks, a child could increase the iconicity of this sign by producing its two-handed variant.

The iconicity of common signs such as CAT suggests one reason why we examine the form of young children’s early signs. Iconic mappings between form and meaning are infrequent in spoken vocabularies. The greater frequency of such mappings in signed languages allows us to test whether young children’s errors in articulating signs could, under suitable circumstances, arise from an attempt to enhance their iconicity. The attraction of iconicity might be such that children’s errors would reveal a lesser role for articulatory constraints analogous to the biomechanical factors that constrain early speech production (e.g., Davis & MacNeilage, 1995).

The two language modalities also differ in articulatory resources. The articulators in sign and speech may place different demands upon the child, and offer him or her different resources. For example, the manual articulators—unlike the oral articulators—are paired; we have two arms and hands. Whereas the oral articulators are largely hidden from view, the manual articulators move in a transparent space. This is one resource that contributes to the potential for iconically- and indexically-motivated signs and that offers a partial explanation for similarities across signed languages in vocabulary (Currie, Walters, & Meier, 2002), pronouns (McBurney, 2002) and verb agreement (Liddell, 2003; Meir, 2002). Lastly, the arms and hands comprise a set of jointed segments, whereas the tongue does not. Despite such impressive differences between the manual and oral articulators, we argue that certain motoric (i.e., articulatory) constraints on children’s production of language are shared by the two modalities; other motoric constraints are modality-specific. We propose articulatory constraints of each type and examine their role in development.

We report three studies: we first examine the effects of children’s errors on the judged iconicity of the signs they attempted. We then examine whether two independently-attested constraints from general motor development predict the form of children’s early signs.

**STUDY 1: ARE CHILDREN LITTLE MIMES?**

Prior studies of the effects of iconicity on child language development generally report that iconicity has little effect on the acquisition of conventional signed languages such as ASL (Newport & Meier, 1985). Studies of the acquisition of verb agreement in ASL (Meier, 1982, 1987), of complex verbs of motion and location (Newport, 1981; Supalla, 1982), and of deixis (Petitto, 1987) have suggested that
children’s acquisition of signed language is seldom determined by the motivated properties of signs. In all three of these linguistic domains, the attested error types yield forms that are less motivated than the adult targets.

However, studies of the invented home sign systems of deaf children of hearing parents show that, in the absence of a conventional language model, deaf children can invent iconic gestures (Goldin-Meadow & Mylander, 1990). Iconicity allows such gestures to be understood. Slobin et al. (2003) have argued that there are effects of iconicity on children’s acquisition of ASL’s so-called classifier constructions. They suggest that iconicity promotes the early (before age 3) emergence and productive use of meaningful handshape distinctions, such as those in “handle classifiers.” Casey (2003) concludes that there are effects of iconic and indexic motivation on the acquisition of ASL verb agreement. Her longitudinal data suggest a developmental continuity between nonlinguistic action gestures and the very similar-looking linguistic use of verb agreement; action gestures and agreeing verbs are alike in indicating the participants of an event through directional movements in space. Casey finds that the directional use of verbs, as in verb agreement, occurs first (at ages 1;6 to 2;1) with verbs such as GIVE, which refer to movement in the world. For these verbs, movement of the sign can be seen as an iconic representation of movement in the world.

Here we revisit the question of whether effects of iconicity can be identified in acquisition; we focus on the very earliest stages of children’s sign production. A prior study examined the effect of iconicity on the composition of young signers’ lexical inventories. Using parental diaries, Orlansky and Bonvillian (1984) argued that iconic signs are not overrepresented among children’s first signs. Launer (1982) tracked early sign production in two deaf children of Deaf parents by examining samples from 1;0,9 to 1;11,16 (Corinne) and 1;5,20 to 2;0,6 (Sally). In roughly 15% of the tokens, the child enhanced the iconicity of the sign in question. For example, for the ASL verb EAT-ICE-CREAM, Sally (1;6) did not move the S-hand (fisted hand) downward past her mouth, as would be expected in the adult language. Instead, she “licked the back of her hand several times, as if the hand itself were the ice cream” (Launer, 1982, p. 168). However, these pro-iconic errors were balanced by counter-iconic errors that constituted about 20% of Launer’s data. For example, Corinne’s (1;2) substitution of 5-hands (all fingers extended and spread) for the fisted S-hands of the two-handed sign CAR obscured the iconic base of that sign (the action of turning a steering wheel).

We now return to the issue of whether iconicity guides children’s early sign production; we ask whether the forms of children’s very earliest signs suggest

---

2As is conventional in the sign literature, the capitalized word “Deaf” refers to deaf individuals who are members of a particular cultural group—the Deaf community—and who are users of that community’s language. Lower-case “deaf” will be used to refer to individuals who have a significant hearing loss, without implications about cultural affiliation.
that they are guided by the iconicity of form-meaning mappings in ASL. Study 1 tested the specific hypothesis that, in their early sign productions, children enhance iconic mappings between form and meaning. Just as past tense overregularizations (e.g., *goed* for *went*) could be seen as evidence of a bias towards morphological transparency, enhancing the iconicity of individual signs could be seen as the product of a bias toward transparent mappings between form and concept. To test this hypothesis, we compared the iconicity of children’s productions to that of the adult targets.

**Methods**

We report longitudinally-collected data on the acquisition of ASL as a first language. We followed four deaf children of Deaf parents, from as early as 8 months and continuing until as late as 17 months. All four are girls; here we call them Caitlin, Katie, Noel, and Susie. Each child has at least one Deaf grandparent; thus each has at least one native-signing parent. With the exception of one child (Katie) who was videotaped monthly, children were videotaped biweekly while interacting at home with a parent or native-signing experimenter.

The gestures captured on videotape were coded as signs only if recognizably related to an adult sign in form and if used in an appropriate context for that sign; one neologism was identified. Fluent signers of ASL, some Deaf and some hearing, coded all candidate signs on various communicative and articulatory dimensions. When 25% of the identified sign tokens were reviewed by two new coders, there was only one disagreement as to whether or not a coded gesture was a sign; that token was excluded from analysis. Altogether, the coders identified 632 sign tokens. The number of tokens per child and the age range sampled for each child are: Caitlin (0;8,0–0;11,7) 45 tokens; Katie (0;11,0–1;5,0) 262 tokens; Noel (0;11,7–1;5,0) 113 tokens; and Susie (0;9,14–1;3,0) 212 tokens. Our subjects attempted adult targets that varied in degree and type of iconicity: some target signs resemble the action to which they refer (*EAT, DRINK, FALL, & HAMMER*); some resemble an action associated with the objects they label (*MILK*—milking a cow, *BOOK*—opening and closing a book); and some depict a part of the animal to which they refer (*CROCODILE*—the jaws, *CRAB*—the claws, *TURTLE*—the head poking from the shell). Other target signs have little iconic basis (*DADDY, MOMMY, FINE, BLACK, & GREEN*).
Children’s signs were rated as to whether they preserved, enhanced, or reduced the iconicity of the adult sign. For this analysis, 605 tokens were considered; some tokens were excluded because the child’s production was partially occluded, because the child’s form was a neologism that had no adult target, or because the sign was idiosyncratic to the child’s family (e.g., a family variant of GRANDMOTHER). A Deaf adult signer judged the iconicity of each token; a second, hearing signer who was blind to our experimental hypothesis rated 18% of the data. Each token was rated on a 5-point scale, with 1 being much less iconic than the adult target, three being neutral (no more or less iconic than the adult target), and five being much more iconic than the adult target. Our coders agreed on 80% of their decisions, Cohen’s Kappa=.67. Agreement was 87% if we simply consider whether a child’s form was judged to be more iconic than the adult sign, less iconic, or neutral with respect to iconicity, Kappa=.75.

Results

Overwhelmingly, the children’s signs were judged to be as iconic as the target sign (that is “neutral”) or less iconic than the adult model; see Table 1. This pattern held for all four subjects; less-iconic errors were significantly more frequent than more-iconic errors, \( p < .002 \) by separate binomial tests on each child. For example, Noel (1;4,25) produced the sign FALL. In the adult language, the dominant hand of this sign has a V-handshape (first and second fingers extended and spread; other fingers fisted); the nondominant hand has a B-handshape (all fingers extended, unspread, with the thumb out). At the outset of this sign, the fingertips of the dominant hand rest on the open palm of the nondominant hand.

### Table 1
The Judged Iconicity of Four Children’s Sign Productions (\( n = 605 \)) as Compared to the Iconicity of the Adult Target Signs

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Caitlin (( n = 45 ))</td>
<td>20.0 (9)</td>
<td>0</td>
<td>80.0 (36)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Katie (( n = 238 ))</td>
<td>10.1 (24)</td>
<td>18.1 (43)</td>
<td>63.4 (151)</td>
<td>7.1 (17)</td>
<td>1.3 (3)</td>
</tr>
<tr>
<td>Noel (( n = 113 ))</td>
<td>28.3 (32)</td>
<td>13.3 (15)</td>
<td>52.2 (59)</td>
<td>6.2 (7)</td>
<td>0</td>
</tr>
<tr>
<td>Susie (( n = 209 ))</td>
<td>25.4 (53)</td>
<td>29.7 (62)</td>
<td>42.1 (88)</td>
<td>2.4 (5)</td>
<td>.5 (1)</td>
</tr>
<tr>
<td>Mean Percentage</td>
<td>20.9</td>
<td>15.3</td>
<td>59.4</td>
<td>3.9</td>
<td>.4</td>
</tr>
<tr>
<td>SD</td>
<td>8.0</td>
<td>12.3</td>
<td>16.2</td>
<td>3.3</td>
<td>.6</td>
</tr>
</tbody>
</table>

*Note.* Children’s sign productions were rated on a scale ranging from “much less iconic” than the adult target sign, to “neutral” (no more or less iconic than the target), to “much more iconic” than the target. The percentage (frequency) of each child’s signs that were assigned to each rating category is reported here.
Then the dominant hand executes an arcing movement, such that at the end of the sign the palm of the dominant hand is oriented upwards with the back of that hand resting on the nondominant palm. The image suggested by FALL is this: a two-legged being that initially stands upright on a flat surface falls onto its back. In Noel’s rendition, she substituted an extended index finger for the V-hand-shape, thereby obscuring the image of a legged being. In her sign, the dominant and nondominant hands moved in tandem, such that both hands moved up and then (forcefully) down; the hands together moved a much greater distance than did the object in the event to which she was referring. Throughout the sign’s production, her extended index finger maintained contact with the palm of the nondominant hand. Thus, in Noel’s sign, the object represented by the dominant hand never falls onto the surface represented by the nondominant hand. And, surprisingly, the surface represented by the nondominant hand is as much in motion as the object represented by the dominant hand.

Only 5% of the children’s forms (33 of 605 cases) were judged to be “somewhat more iconic” or “much more iconic” than the adult target, whereas 39% (238 tokens) showed decreased iconicity. A “somewhat more iconic” token from Noel (1;0,15) involved the noun MILK. This one-handed noun has a simple opening-and-closing movement of the fisted dominant hand. The morphologically-related verb MILK is two-handed and suggests the act of milking a cow: the dominant and nondominant hands execute, in alternation, a repeated downward path movement with a simultaneous closing movement of the hand. Because Noel produced a two-handed version of the noun MILK (albeit without the downward movement of the highly-iconic verb), our coders agreed that her form was somewhat more iconic than the adult target.

In the entire data set, just four tokens were judged to be much more iconic than the adult target. One example was Katie’s production of EAT at 1;4,3. In her rendition of this sign, she held a cookie in her active hand (she did not take a bite out of it) and produced mouth movements that mimicked eating. To recognize the iconicity of EAT—unlike MILK—the child need have little extralinguistic, cultural knowledge (i.e., no knowledge of the dairy industry is required); this fact—along with the mimetic mouth movements—makes it plausible to assume that Katie was manipulating the iconic value of this sign. Another example judged to have much enhanced iconicity was Susie’s production at 1;2,23 of the sign TASTE with tongue protrusion. One-third of the tokens judged to have enhanced iconicity (11 of 33) were distinguished by the child’s addition of mimetic facial movements. In these instances, nonmanual articulators on the face and head—not the manual articulators—were the exponents of enhanced iconicity.

The just-reported analysis might be criticized in the following way. Some of the signs that the children attempted have no obvious iconic basis. For example, in the sign DOLL, the dominant X-hand (first finger extended and bent at the second knuckle; other fingers fisted) executes a repeated, downward brushing
movement at the tip of the nose. It is not obvious how a child, or an adult, might enhance the iconicity of this sign. To address this critique, we examined a set of one-handed signs for animals and other animate beings; among these signs are *cat, cow, deer*, and *horse*. The images suggested by these signs are, respectively, the cat’s whiskers, the cow’s horns, the deer’s antlers, and the horse’s ears. The iconicity of these signs can readily be enhanced by using a two-handed variant (cf. Frishberg, 1975). Only one of the 20 tokens of these signs in our sample was judged to be more iconic than the adult target. Moreover, all 20 tokens were one-handed, even the typically two-handed sign *MICKEY-MOUSE*.

In a second follow up, we examined errors on place of articulation. Infants are much more accurate on place than on other aspects of sign formation (Meier, 2006). Compared to handshape which requires considerable fine motor control, there may be few motoric constraints on children’s production of place (Conlin, Mirus, Mauk, & Meier, 2000). Therefore, in this domain of sign formation, there may be few motoric constraints that would bar a child from enhancing iconicity. Of 120 tokens containing a place error that could be evaluated with respect to iconicity (errors violating the sign space as a result of over-extension of the arms were excluded here), only nine (7.5%) were judged to have enhanced iconicity (all “somewhat more iconic”), whereas 61 errors (50.8%) depressed iconicity. A striking example is Susie’s (1;1) production of *FLOWER*, which for the adult makes contact on the face, once near each nostril (as if sniffing a flower). In her production, the sign contacted her ear. There is no evidence that this class of 120 place errors is driven by an attempt to enhance iconicity on the part of children.

**Discussion**

Signed and spoken languages differ in the resources available to them; in particular, the visual-gestural modality grants richer and more frequent opportunities for iconic representation to signed languages than the oral-aural modality accords spoken languages (Newport, 1981). The ability of children to use this resource is on display in the home sign systems of deaf children of hearing parents; with little help from non-signing parents, these children develop a lexicon of highly-motivated gestures (Goldin-Meadow & Mylander, 1990). Aside from pointing gestures, the gestures of home-signing children typically have their basis in iconic representation of action (Feldman, 1975). Consistent with this, the one home-signer whose pertinent development has been examined in detail used iconic gestures in ways that were verb- or adjective-like through age 3;5; noun-like use of such gestures emerged later (Goldin-Meadow, Butcher, Mylander, & Dodge, 1994).

Paradoxically, the potential for iconic representation that is afforded by the visual-gestural modality and that is exploited by home-signing children seldom results in children’s earliest ASL signs being more iconic than their adult targets;
much more frequently, children’s earliest signs are less iconic than the target
signs. Why do home-signing children differ from children in signing families?
When home-signers innovate gestures, they presumably produce forms that are
well-suited to their concurrent articulatory capacities; these children do not have
parents who model forms that lie beyond their articulatory capacities. Home-
signing children therefore have freer rein to exploit the resources of the visual-
gestural modality; indeed they must do so, if they are to be understood. In con-
trast, children born into Deaf signing families are largely obliged to produce the
conventional forms presented to them, just as hearing children are largely obliged
to produce the words that their parents model.

Our results here have revealed a small number of forms (5% of the data) that
showed enhanced iconicity vis-à-vis the adult target. Older children might show
greater effects of iconicity: Launer’s (1982) data came from somewhat older sub-
jects (through 24 months) and included more pro-iconic errors. Namy, Campbell,
and Tomasello (2004) report experimental evidence that 26-month olds, but not
18-month olds, are sensitive to the iconicity of novel nonlinguistic gestures. In
general, older children might be expected to be more sensitive to the iconicity of
signs, because of their expanding nonlinguistic knowledge and growing metalin-
guistic awareness. It may also be that careful analyses of particular classes of
signs would show more evidence of enhanced iconicity in children’s output. For
example, Launer may have found more frequent pro-iconic errors because there
appear to have been more verbs in her sample. Verbs constituted approximately
11% of the tokens (<20% of the types) in our data; the relative size of our sub-
jects’ verb vocabularies accords with the results from a larger sample of children
who were examined using the ASL version of the MacArthur Communicative
Development Inventory (Anderson & Reilly, 2002). Future research might exam-
ine whether the iconicity of ASL verbs is more transparent to children than that
of nouns. In particular, children could be more sensitive to iconic representations
of how objects move or how humans handle objects than they are to iconic repre-
sentations of the shape of objects or of parts of objects.

Our conclusion is this: although we have identified some instances in
which infants enhanced the iconicity of adult signs, our results do not reveal a
major role for iconicity in shaping the forms of children’s earliest signs. Errors that yielded forms that were less iconic than the adult target were much
more frequent than errors that enhanced iconicity. However, the fact that there
were few errors that enhanced iconicity does not demonstrate that children are
insensitive to it. The iconicity of signs such as MILK (the action of milking a
cow) may not be recognized by children; some other early-learned signs (e.g.,
MOTHER) are almost fully arbitrary and are not likely candidates for enhanced
iconicity. Even the large set of errors in which the child’s form was less iconic
than the adult target do not demonstrate that children are unaware of the
iconicity of these signs; instead it may be that the articulatory constraints on
children’s sign production were not loosened by whatever iconicity the child recognized.

Given that we see no reason to think that children actively seek to depress the iconicity of signs, we must look to factors besides iconicity if we are to explain the preponderance of children’s errors. For example, Cheek, Cormier, Repp, and Meier (2001) observed that, in linguistic and nonlinguistic action, infants may have difficulty inhibiting one hand when the other is active. In signing, this may be most apparent in two-handed signs, such as FALL, in which the nondominant hand must remain static while the dominant hand moves. Noel’s production of FALL at 1;4,25 was markedly less iconic than the target, in part because her nondominant hand mirrored her dominant hand. We now test two further constraints derived from the literature on infant motor development.

**STUDIES 2 AND 3: MOTORIC DETERMINANTS OF THE FORM OF CHILDREN’S EARLY SIGNS**

In sign, as in speech, there is a large set of articulatory specifications that the child must acquire. Accordingly, there is also a large set of hypotheses that can be developed to account for detailed aspects of child sign production. Analyses of the phonology and phonetics of signed languages (notably, Stokoe, 1960) have long recognized three major parameters of sign formation: place of articulation, handshape, and movement. Here we focus on movement. Two factors drawn from the literature on infant motor development will help us understand how young children acquire and produce sign movement:


2. Proximalization of movement: Development of motor control generally proceeds from proximal articulators (e.g., the shoulder) to distal ones (e.g., the wrist and fingers). Children may use proximal articulators when adults would use more distal ones.

Why these two factors? Each has received considerable attention in the literature on infant motor development. Both have important consequences for the expression of linguistically-significant contrasts in ASL. Moreover, the two factors have implications for children’s production of every sign in our corpus. Importantly, one

---

4In principle, a hypothesized failure to inhibit the nondominant hand could also explain some instances in which a child apparently enhanced the iconicity of a sign. For example, our data yield four instances in which a child produced a two-handed form of the one-handed noun milk; all were judged to be more iconic than the adult target.
of these motoric factors, proximalization of movement, is likely to be unique to
sign. In contrast, a propensity to repetitive action could characterize children’s
performance in sign and speech. Thus, despite the very different looking articula-
tors in sign and speech, certain motoric tendencies may be common to language
development in the two language modalities. To assess the effects that these fac-
tors have on infant sign production, we examine the same database of early signs
as in Study 1.

Study 2: Cyclicity
A phonetic property of ASL signs is that some have a single movement (e.g., the
signs BLACK, WHITE, and DAY), whereas others have repeated movements (e.g.,
YELLOW, BALL, and CAT). Control over repetition is necessary for the expression
of important morphological contrasts in ASL: in derivationally-related noun-verb
pairs such as CHAIR and SIT, the noun has a short, repeated, restrained movement,
whereas the longer movement excursion of the verb may—depending on the verb
in question—be either single (like SIT) or repeated (Supalla & Newport, 1978). In
addition, several aspectual morphemes in ASL have distinctive patterns of
repeated movement (Klima & Bellugi, 1979). Thus, controlled use of repetition
is necessary for mature production of lexical signs and of the inflectional and
dervational morphology of ASL.

The Development of Repeated Movements
Across many motor domains, infants exhibit repetitive, stereotypic movement
patterns (Thelen, 1979). These movements range from the infant’s repetitive,
alternating kicking, to stereotypic arm waves, and perhaps to reduplicative vocal
babbling. MacNeilage and Davis (1993) argue that early vocal babbling consists
largely of a simple oscillation of the mandible, with little independent control
over tongue position. Davis and MacNeilage (1995) report that most utterances
during the babbling period consist of more than a single syllable; they found that
variation in the amplitude of mandibular oscillation was the main source of pho-
netic differences between syllables (yielding utterances such as [dædi], in which
the two vowels differ on height rather than backness). Meier, McGarvin, Zakia,
and Willerman (1997) showed that, in many hearing and deaf infants, phonated
vocal babbling may alternate—even within a single utterance—with silent man-
dibular oscillations. On the view of Thelen (1991), cyclic repetition is an attractor
state for the developing infant system.

In work on prelinguistic gesture in deaf and hearing children (Cheek et al.,
2001), we analyzed prelinguistic gestures from five hearing children with no sign
exposure and five deaf children (including Katie & Noel) who were born into
Deaf, signing families. Those gestures with no evident referential, communicative,
or manipulative purposes were labeled manual babbles. Meier, Cheek, and Moreland (2002) counted the number of movement cycles in each manual babble in that sample. The median number of cycles per manual babble (n=279) was four for hearing and deaf infants alike. The great preponderance of manual babbles in this sample (over 75% of the babbles produced by deaf children) was multicyclic; that is, they had repeated movement. However, children, both deaf and hearing, inhibited repetition in their production of certain communicative gestures that emerged at 10 months (Meier & Willerman, 1995).

The Current Study

Here we examine the occurrence of repetitive, cyclic movement patterns in children’s first signs. Such cyclic movements are characteristic of many infant motor patterns, whether linguistic or non-linguistic and whether oral or manual. Prior reports of the transition between manual babbles and first signs (Petitto & Marentette, 1991; Cheek et al., 2001) have demonstrated that, on many parameters of sign formation, there is a smooth transition between manual babbling and first signs. Given this, we hypothesize that a statistical preference for repetitive movement patterns will persist into the early sign period. In their first words, speaking children are quite accurate in the production of consonantal segments that are drawn from the babbling “repertoire” (Locke, 1983). When they attempt consonants that lie outside this repertoire, children tend to substitute consonants drawn from within it. Similarly, we hypothesize that signing children will be accurate in the production of signs that have repeated movement and that they may err by producing repeated movement even when the adult form demands a single movement cycle. However, if children are able to inhibit a tendency toward repeated movement (as in children’s production of communicative gestures), we should expect few errors on adult target signs that have a single movement cycle.

Methods

We examined the same database of signs as in Study 1. For each token, we coded whether it was mono- or multicyclic, that is, whether its movement was single or repeated. We also coded the number of movement cycles per token. A few tokens were excluded because their movement was occluded. Coding reliability was 80.4%; we considered coding decisions to be reliable if the two coders differed by no more than one movement cycle, but the coders had to be in full agreement if either coded a token as having just one cycle. Reliability on the decision as to whether a child’s sign was mono- or multicyclic was high, with 94.1% intercoder agreement (Cohen’s Kappa=.77). In analyzing the data, we will compare the children’s productions to the videotaped productions of a highly fluent Deaf
teacher of ASL who has been a longtime resident of the same state in which our subjects were raised. We asked him to produce each sign that we identified in the children’s signing; in doing this he referred to a list of English glosses. He was also asked to produce any variant forms that he knew. This signer’s productions were then coded on the same articulatory parameters as the children’s signs.

Results

An analysis of 625 early signs showed that the median number of cycles per sign was three cycles, with the number of cycles per sign ranging from 1 to 37; see Figure 1. The median number of cycles in the individual samples was two for Katie, three for both Noel and Susie, and six for Caitlin. Although the mode is one cycle per sign, fewer than 25% of the early signs were monocyclic. On average, 19.5% (SD=10.3) of the children’s tokens had a single cycle.

As noted above, we hypothesize that children will preserve repeated movement in signs whose adult targets have repetition. We also expect that children may add repetition to signs with monocyclic (i.e., non-repeated) adult targets. We tested this prediction by assessing the accuracy of each one of the children’s sign tokens; see Figure 2. Because in some instances we could not determine whether the target sign was mono- or multicyclic, only 536 tokens entered into this analysis.5

![Cyclicity in Early Signs](n=625)

FIGURE 1 Number of movement cycles per sign in a pooled sample (n=625) of the signing of 4 deaf children of Deaf parents. Note gaps in the X-axis at 21–24, 26–27, and 30–36 cycles.

5For example, we could not determine whether the monocyclic sign EAT or its multicyclic derived form FOOD was the target in certain contexts.
Examples of monocyclic target signs included \textit{thank-you} and \textit{black}; examples of multicyclic target signs included \textit{car}, \textit{horse}, and \textit{mother}. When repetition in the child’s sign did not match the adult model, the child’s production was considered an error.

Most of the sign tokens that the children produced have multicyclic targets in the adult language (mean proportion of each child’s tokens=.81, SD=.13). The children made a total of 151 errors, 81 on monocyclic targets versus 70 on multicyclic targets. The children generally erred when attempting signs that have a single movement cycle in the adult language. Considering single-cycle targets separately, the mean error rate was .66 (SD=.15; Caitlin excluded due to insufficient data). In contrast, the children’s productions of multicyclic targets were generally correct (mean error on multicyclic targets =.18; SD=.10; Caitlin again excluded). Chi-square analyses showed that, for three of the four children, the frequency of correct versus incorrect productions differed significantly for monocyclic versus multicyclic target signs: 1) for Katie, monocyclic targets: 10 correct, 20 errors; multicyclic targets: 122 correct, 45 errors, \( \chi^2(1)=18.15, p < .001 \); 2) for Noel, monocyclic targets: 14 correct, 14 errors; multicyclic targets: 61 correct, 14 errors, \( \chi^2(1)=10.11, p < .01 \); and 3) for Susie, monocyclic targets: 12 correct, 47 errors; multicyclic targets: 125 correct, nine errors, \( \chi^2(1)=105.83, p < .001 \). These three children each showed higher error rates for monocyclic targets than for multicyclic targets. For the fourth child (Caitlin), empty cells in the data precluded this test.

As noted, the children often erred by adding repetition to signs that have non-repeated movement in adult ASL. For example, the sign \textit{black} has a single movement cycle in the adult language (generally, an inward twist of the forearm).
At 1;0,6, Noel produced this sign with 6 cycles; altogether she produced seven multicyclic tokens of BLACK in the samples from age 0;11,6 to 1;1,28. Similarly, the sign LIGHT (as in a source of illumination) should have a one-time opening movement of the hand. Susie (1;0,14) produced this sign with a repeated wrist nod (also 6 cycles). Susie’s addition of repetition to this monocyclic target sign may have contributed to the fact that, in Study 1, this token was judged to have been less iconic than the adult target.

For each of the four children, most of the sign tokens that they produced were multicyclic renditions of multicyclic targets (mean proportion of all sign tokens=.70; $SD=.16$). For the set of tokens with multicyclic targets, the mean proportion of multicyclic productions was .82 ($SD=.10$); for monocyclic targets, the mean proportion of multicyclic productions was .66 ($SD=.15$). A further set of analyses on the same data as treated above examined Noel, Susie, and Katie’s production of mono- or multicyclic output forms as a function of whether the adult target sign was mono- or multicyclic. Caitlin was again excluded because of empty cells. A chi-square test revealed a significant effect for Noel [monocyclic targets: 14 monocyclic productions, 14 multicyclic; multicyclic targets: 14 monocyclic productions; 61 multicyclic, $X^2(1)=10.11, p<.001$]. A significant effect of target type was also found for Susie [monocyclic targets: 12 monocyclic productions, 47 multicyclic; multicyclic targets: 9 monocyclic, 125 multicyclic, $X^2(1)=7.84, p<.01$], but not for Katie ($X^2(1)=.52, NS$). For Noel and Susie, multicyclic productions were more likely if the target was multicyclic. The significant results for Noel and Susie suggest that these children were learning to inhibit repetition in their productions of single-movement target signs. For Susie, 80% of her productions of monocyclic targets had repeated movement, whereas 93% of her productions of multicyclic targets had repeated movement. For Noel, the difference was more impressive: only 50% of her productions of monocyclic targets were repeated in contrast to 81% of her productions of multicyclic targets.

We did not find strong evidence that Noel reliably produced any particular monocyclic sign with just one movement cycle, although she produced the sign FALL with a single movement in five of seven tokens.

Discussion

Repetitive movement patterns are characteristic of linguistic and nonlinguistic behavior in infancy; the results reported here indicate that repetitive movements characterize the signing of deaf infants. In this sample of early signs, as in the sample of nonreferential manual babbles described in Meier et al. (2002), more than 75% of the tokens were multicyclic. It seems that repetitive movements are not costly for infants. To the contrary, a bias toward repeated movement offers an explanation for an important error pattern in early signing; specifically, infants tend to add repetition to signs that have one-time movements in the adult
language. This result has also been observed in a case study of a child acquiring British Sign Language (Morgan, Stoneham, & Jones, 2007). Nonetheless, repetition is not inevitable: the communicative gestures produced by three deaf and two hearing infants studied by Meier and Willerman (1995) were predominately single-cycle gestures. Two children in our current study showed limited success at inhibiting repetition when they produced single-cycle target signs. In the speech literature, a longitudinal study of four infants from roughly 7 to 18 months showed that early words had a lower rate of full syllable repetition than did prelinguistic babbling (MacNeilage, Davis, & Matyear, 1997). Thus, repetition is a favored outcome in infants in the age range of our subjects, but is not inevitable when they have a non-repeated target in mind.

Environmental effects may converge with the motoric biases of infants to yield the high proportion of multicyclic infant sign productions reported here. Meier and Willerman (1995) found preliminary evidence that, by comparison to the nonreferential gestures (“manual babbles”) of hearing infants with no sign exposure, a somewhat higher proportion of the nonreferential gestures of deaf infants were multicyclic. Our current results, as well as this earlier finding, may reflect the fact that a large fraction of ASL signs have repeated movement (cf. Channon, 2002, for discussion of the adult lexicon). In contrast, repetition of consonants in CVC and CVCV words is disfavored in adult spoken languages (MacNeilage, Davis, Kinney, & Matyear, 2000). One account for why signing children so favor repetition in early signs (as opposed to communicative gestures) might suggest that these children have begun to abstract a template for the form of ASL signs. An examination of the use of repeated movement by homesigning children might shed light on the extent to which the patterns reported here are a product of the linguistic model that was available to our subjects.

Repeated movement is also characteristic of child-directed signing (Moores, 1980). In an analysis of maternal production of morphologically-related noun-verb pairs such as SIT and CHAIR, Launer (1982) reported that maternal signs had up to 12 movement cycles; she also reported that repetition was sometimes used ungrammatically with verbs that are expected to have a single movement cycle. Holzrichter and Meier (2000) analyzed 12 signs that are common in child-directed signing; all have repeated movement (generally 2–3 cycles) in their citation forms. Inspection of 173 child-directed tokens of these signs revealed that 37% were produced with more than three movement cycles. One mother produced a token of the sign MORE with 16 cycles; such tokens may be a model for children’s production of signs with a high number of cycles (again see Figure 1). Holzrichter and Meier speculated that, by adding movement cycles to a sign, the mother increased the likelihood that her child would see that sign. Children who produce signs such as COOKIE with 11 cycles (e.g., Susie at 0;11,23) may likewise be concerned that the mother see the sign.
In sum, motoric factors may converge with effects of the input environment to yield an infant tendency toward repeated sign movement. Further research is needed to separate effects of the infant motor system from those of linguistic input and to determine when children can inhibit a tendency toward repetition.

Study 3: Proximalization of Movement

The arms and legs are segmented limbs in which certain joints—the shoulder and hip—are close to the torso whereas others—those in the hand or foot—are remote from the torso. It has long been suggested that infant motor development proceeds from proximal to distal articulators (Gesell & Thompson, 1934); the result is that infants seem to show relatively better control of proximal articulators and may use proximal articulators in tasks in which adults would use more distal ones; see Jensen, Ulrich, Thelen, Schneider, and Zernicke (1995) on kicking in babies, and Saida and Miyashita (1979) for a study of writing skills in preschoolers.

Why might children proximalize? On one account, proximalization of movement in infants could be understood as a product of immature motor development. However, proximalization could also be a strategy by which learners—children and adults—cope with the task of acquiring a new motor skill. Skilled use of the arm, whether in signing or writing or throwing, requires the control of a number of free parameters (so-called degrees of freedom) associated with the various joints of the arm. Skilled use of the distal articulators depends on skilled use of proximal articulators, whereas the converse is not true. By limiting movement at distal articulators, the learner of a new skill can limit the number of parameters that must be controlled in planning and executing movements.

Consistent with the suggestion that movement proximalization is not simply a function of immaturity; the proximal-to-distal trend has been observed in adults. Adults asked to write with their nondominant hand use large movements of the proximal articulators of the arm and continue to do so even with extensive practice (Newell & McDonald, 1994). Certain brain-damaged populations, for example ideomotor apraxics, tend to use more proximal movements when they gesture, in comparison to individuals without brain damage (Poizner, Mack, Verfaellie, Gonzalez Rothi, & Heilman, 1990).6 Lastly, naive hearing adults frequently proximalize when imitating signs (Mirus, Rathmann, & Meier, 2001).

As suggested, the joints of the arm and hand can be placed on a proximal-to-distal scale:

---

6Proximalization is not an inevitable consequence of damage to neuromotor systems. Deaf Parkinsonian signers exhibit distalized, reduced signing (Brentari & Poizner, 1994).
The term “radioulnar joint” refers to the articulations of the radius and ulna in the forearm; movement at this joint (through contraction of pronator and supinator muscles) yields a rotation of the forearm, which is perceived as a change in palm orientation. We will often refer to this movement as “forearm twist.” The first knuckle (K1) is the metacarpophalangeal joint and the second knuckle (K2) is the proximal interphalangeal joint. Examples of ASL signs whose lexical movement is typically restricted to each of the joints listed on this proximal-to-distal scale include: COMMITTEE (shoulder); THANK-YOU (elbow); BLACK (radioulnar); YES (wrist); BIRD (first knuckles); and BUG (second knuckles). These signs are illustrated in Figure 3. This figure also shows examples of the two shoulder categories that we distinguish: “shoulder” as in signs such as COMMITTEE or ANIMAL (in this instance, shoulder abduction/adduction) or “shoulder twist” as in DAY (longitudinal rotation of the arm at the shoulder). Some of these signs warrant further description: The C-handshape of the sign COMMITTEE contacts the upper chest twice, once on each side of the midline; this movement is largely executed at the shoulder, thereby drawing the arm across the chest. In articulating the sign DAY, the arm rotates inward at the shoulder; this is a shoulder twist. The sign BLACK exemplifies a forearm twist; the result of this movement is that the tip of the extended index finger grazes the forehead. In the sign BUG, the first and second fingers bend repeatedly at the second knuckles.

Whether these or other signs are phonologically specified for articulation at a particular joint is unresolved. Although articulation at the joints mentioned here is typical of the signs cited above, the particular joint that a signer uses may vary as a function of register (e.g., shouting vs. whispering) and distance between signer and addressee (Brentari, 1998; Crasborn, 2001). Thus, the sign YES can be proximalized when stressed; the nodding movement of the hand is then executed, not by the wrist, but by inward rotation of the arm at the shoulder (shoulder twist).

---

7 Even in the adult, articulation at the distal interphalangeal joint (the third knuckles) is generally not independently controlled and therefore this joint is omitted here.

8 The path of the hand in COMMITTEE is a shallow arc; the movement away from the chest is executed by a small extension and flexion at the elbow.

9 Native signers vary in how they produce the citation form of BLACK; some prefer a movement from the shoulder. Our adult model produced BLACK with a shoulder movement and thus we did not consider children’s tokens that employed the shoulder to have been errors. In this respect, our estimate of the frequency of children’s proximalizations is conservative.
Fig. 3  Examples of signs articulated at the joints of the arm and hand. The abbreviations K1 and K2 indicate the first and second knuckles, respectively.
As a first step in our analyses of the early sign data, we report the frequency and accuracy with which signing children used each of the joints in the arm and hand. By understanding which joints children control, we will have an appropriate context for understanding their errors. This analysis is also of independent interest, inasmuch as it has been argued that a single oscillator (the mandible) constrains syllable production in the infant speech-motor system and that the speaking infant has limited control of oscillators other than the mandible (MacNeilage & Davis, 1993). We ask whether infant signing is similarly constrained to a single major oscillator. We then report three tests of the hypothesis that infants tend to proximalize sign movements.

Methods

We coded children’s joint usage in each of the 632 sign tokens in our database. The coding system admitted 12 possibilities: shoulder, shoulder twist, elbow to/fro, forearm twist, wrist up/down, wrist sideways, first knuckles (K1), second knuckles (K2), thumb, torso, none, and occluded. These categories could be used in combination inasmuch as the child’s articulation of a sign might involve more than one joint. To facilitate coding, we developed heuristics for identifying articulation at particular joints:

1. Shoulder (glenohumeral joint). If the subject’s elbow changed position relative to the torso (implying movement of the upper arm), “shoulder” was coded.
2. Shoulder twist (internal or external rotation at glenohumeral joint). Coded if the elbow remained in the same position relative to the torso, while the upper arm rotated about its long axis. The typical result was that the forearm appeared to move in an arc around the elbow, as in the ASL sign DAY.
3. Elbow to/fro. Coded if a change in the angle between forearm and biceps was seen.
4. Forearm twist (radioulnar joint). Coded if rotation about the long axis of the forearm caused the hand to pronate or supinate.
5. Wrist up/down (radiocarpal joint). Flexion or extension of the hand. If the angle between the palm and the underside of the forearm changed, wrist up-down movement was coded.
6. Wrist sideways (radiocarpal joint). Adduction or abduction of the hand caused the angle between the edge of the hand and side of the forearm to change, as in the sign CHEESE.
7. First knuckles (K1, or metacarpophalangeal joint). The knuckles most proximal to the wrist. A change in the angle relating the fingers to the palm indicated use of K1.
8. Second knuckles (K2, or proximal interphalangeal joint). The second group of knuckles away from the wrist. If the angle between the proximal
and middle segments (proximal and middle phalanges) of the fingers changed, K2 was coded.

9. Thumb. Interphalangeal joint of the thumb, used in the signs TURTLE and TWENTY-ONE.

10. Torso. Rotation of the torso about its vertical axis.

11. None. Used if the identity of a sign was clear but no movement was apparent.

12. Occluded. Coded if a child articulated a recognizable sign, but the utilized joints were out of the camera’s view.

Intercoder reliability on these coding decisions was satisfactory; the coders agreed on 78% of their decisions (Cohen’s Kappa=.73). Signs coded as “none,” “occluded,” or “thumb” are excluded from the analyses reported below, as are signs idiosyncratic to a given family. Signs coded as “thumb” are excluded because only eight instances were identified and our coders did not use the category consistently. The two wrist categories are combined as “wrist”; there was only one coded instance of wrist-sideways. In analyzing the data, we will, as in Study 2, compare children’s productions to those of a highly fluent adult model.

Results

A set of 518 sign tokens was available for analysis. Of these, 166 were correct; that is, they matched the adult target. We first consider the accuracy of children’s usage of the joints of the arm and hand. We then test children’s tendency to proximalize movement by analyzing the errors our subjects produced.

Accuracy of Joint Usage

The representation of the seven coded joints in the 95 adult sign types attempted by the children is: shoulder (13), shoulder twist (23), elbow (26), forearm (18), wrist (13), K1 (15), and K2 (2). Every joint except K2 was well-represented in these adult signs. Each child’s use of the coded joints is summarized in Table 2. For each joint, the child’s accuracy (i.e., the number of correct productions divided by the sum of correct productions and omissions) and proportion overuse (i.e., number of incorrect usages divided by the sum of correct and incorrect usages) are reported. Table 2A suggests that individual children used the shoulder twist (Katie & Noel, as in Katie’s sign BALL at age 1;3,0), elbow (Katie & Susie, as in Katie’s sign EAT at 1;2,6), and K1 (Katie, Noel, & Susie, as in Noel’s sign HORSE at 1;3,12) with fair accuracy (i.e., more correct usages than omissions). The children either showed low accuracy in using the shoulder, forearm, wrist, and K2, or they produced few signs that required articulation at those joints (e.g., Katie produced 12 tokens with the
shoulder as a target joint and just five tokens with a K2 target). Averaged across the four children, two joints were produced with 50% accuracy or better: the elbow and K1 (but note the limited data on K1 from Caitlin). Accuracy was low on the forearm and, notably, the wrist.

Mature production of signs is reflected not just by the use of a joint when it is called for, but also by the inhibition of articulation at joints not appropriate to the adult target. Successful inhibition of non-targeted joints is reflected in a low rate of overuse. As Table 2 reveals, there were three joints—the shoulder, wrist, and K2—for which the preponderance of children’s usages were incorrect. The hypothesis that infants tend to proximalize movement leads one to anticipate that overuse (errors of commission) will be high for the most proximal joints and low for the most distal joints. Notably high overuse rates (0.80–1.0) were indeed shown for the shoulder by all four subjects. A high overuse rate (0.67) occurred for shoulder twist in Susie’s data, and moderate overuse rates (0.42–0.56) for the elbow appeared in the data from Noel, Susie, and Caitlin. The generally high frequency of errors of commission on these proximal joints

<table>
<thead>
<tr>
<th>Joint</th>
<th>Caitlin</th>
<th>Katie</th>
<th>Noel</th>
<th>Susie</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Accuracy by Joint</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td>.00 (1)</td>
<td>.58 (12)</td>
<td>.30 (10)</td>
<td>.22 (9)</td>
<td>.37 (.19)</td>
</tr>
<tr>
<td>Sh-Twist</td>
<td>.00 (32)</td>
<td>.67 (57)</td>
<td>.64 (14)</td>
<td>.23 (39)</td>
<td>.38 (.33)</td>
</tr>
<tr>
<td>Elbow</td>
<td>.29 (31)</td>
<td>.82 (62)</td>
<td>.29 (24)</td>
<td>.60 (35)</td>
<td>.50 (.26)</td>
</tr>
<tr>
<td>Forearm</td>
<td>.00 (1)</td>
<td>.00 (5)</td>
<td>.39 (28)</td>
<td>.15 (26)</td>
<td>.18 (.20)</td>
</tr>
<tr>
<td>Wrist</td>
<td>.00 (2)</td>
<td>.00 (20)</td>
<td>.00 (14)</td>
<td>.17 (24)</td>
<td>.06 (.10)</td>
</tr>
<tr>
<td>K1</td>
<td>.00 (2)</td>
<td>.86 (49)</td>
<td>.83 (18)</td>
<td>.73 (56)</td>
<td>.81 (.07)</td>
</tr>
<tr>
<td>K2</td>
<td>NA (0)</td>
<td>.80 (5)</td>
<td>NA (0)</td>
<td>1.00 (1)</td>
<td>–</td>
</tr>
<tr>
<td>B. Overuse of Joints</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder</td>
<td>1.00 (28)</td>
<td>.80 (35)</td>
<td>.89 (26)</td>
<td>.95 (39)</td>
<td>.91 (.09)</td>
</tr>
<tr>
<td>Sh-Twist</td>
<td>NA (0)</td>
<td>.12 (43)</td>
<td>.36 (14)</td>
<td>.67 (27)</td>
<td>.38 (.28)</td>
</tr>
<tr>
<td>Elbow</td>
<td>.47 (17)</td>
<td>.16 (61)</td>
<td>.56 (16)</td>
<td>.42 (36)</td>
<td>.40 (.17)</td>
</tr>
<tr>
<td>Forearm</td>
<td>NA (0)</td>
<td>NA (0)</td>
<td>.00 (11)</td>
<td>.33 (6)</td>
<td>.16 (.23)</td>
</tr>
<tr>
<td>Wrist</td>
<td>NA (0)</td>
<td>1.00 (10)</td>
<td>1.00 (1)</td>
<td>.89 (35)</td>
<td>.94 (.08)</td>
</tr>
<tr>
<td>K1</td>
<td>1.00 (1)</td>
<td>.16 (50)</td>
<td>.17 (18)</td>
<td>.09 (45)</td>
<td>.14 (.04)</td>
</tr>
<tr>
<td>K2</td>
<td>1.00 (1)</td>
<td>.73 (15)</td>
<td>1.00 (11)</td>
<td>.96 (22)</td>
<td>.90 (.15)</td>
</tr>
</tbody>
</table>

Note. Each child’s proportion correct usage is reported in (A); the number of target sign tokens with that joint appears in parentheses. Table B reports each child’s overuse of movement at the target joints; the proportion overuse is the number of overuses divided by the total number (in parentheses) of tokens in which the child used the joint in question. Cells with two observations or fewer are not included in reported means or standard deviations.
conforms to our general expectation that infants will overuse them. Two children—Susie and Katie—showed a high rate of overuse of the wrist. Overuse rates for intermediate joints such as the forearm or wrist can only be understood in light of whether the adult target joint was more proximal or more distal than the joint used by the child. Three children showed frequent overuse of K2. The high frequency of overuse on this most distal of the coded joints is a surprise and merits further analysis below.

In sum, the data in Tables 2A and B suggest that infants control, to varying degrees, three oscillators involved in the articulation of signs: the shoulder (considering the two shoulder categories together), elbow, and K1. A better understanding of the data, including the data on K2, will come from analysis of the subjects’ errors.

**Error Analyses**

When the child’s form did not match the form produced by the adult model, we considered the child’s production to be an error; some but not all these errors are ungrammatical in ASL. A total of 352 errors were identified. We developed three hypotheses as to the kinds of errors that children would make if proximalization of movement characterizes early signing. We hypothesize that children are more likely to err by substituting a proximal articulator for a distal one, than vice versa. Similarly, distal articulators are more likely to be omitted, because they are argued to be less well-controlled in general. And, if an articulator is added, it is likely a well-controlled proximal articulator, not a more poorly controlled distal one.

1. Hypothesis 1: If the child substitutes an unexpected joint for the target, the substitute will be proximal to the target joint. We tested this hypothesis in the following way: we defined a substitution error as the replacement of an adult target joint by an unexpected joint. If the child made a substitution for a shoulder or K2 target, that substitution was excluded from the analysis because the target was either maximally distal or maximally proximal. There were 120 substitutions in our data. When children substituted an articulator that would not be expected in the adult sign, they strongly favored proximal articulators over distal ones. All infants, including Caitlin who produced few pertinent tokens (3 proximal substitutions, 0 distal), substituted proximal joints more than distal joints when they erred: for

---

10Alone among the children, Susie produced frequent errors of commission at the wrist. Of 35 tokens of wrist use, 4 matched the target sign; 21 (60%) were produced instead of, or in conjunction with, a more distal movement at K1 and/or K2. Other instances of overuse of the wrist may reflect floppy movement associated with a poorly formed, lax handshape.
Katie, 22 proximal substitutions versus 9 distal, $p < .05$ by the binomial test; for Noel, 25 proximal, 2 distal, $p < .001$; and Susie, 52 proximal, 7 distal, $p < .001$. Summed across children, proximal substitutions exceeded distal substitutions for each of these target joints: for the elbow, 34 proximal, 2 distal; for the forearm, 17 proximal, 9 distal; for the wrist, 29 proximal, 4 distal; and for K1, 22 proximal, 3 distal.

Here are examples of proximalization: At 0;11,23, Susie produced the sign HORSE with a nodding movement of the wrist instead of the repeated bending of the extended index and middle fingers at K1 that is expected in the adult language. At 1;2,20, Noel substituted movement at the shoulder for the repeated movement at the elbow that is expected in the sign DADDY. Thus, she brought the hand to contact with the forehead by raising the arm from the shoulder. Lastly one variant of the sign KITE is produced with a repeated bending of the wrist, along with an upward movement of the arm from the shoulder. At 1;3,12, Noel proximalized the movement of the sign in such a fashion that there was no arm or wrist movement whatsoever, although her arm was in the expected posture for this sign. Instead movement was restricted to a twisting movement of the torso. In this instance, proximalization of movement likely contributed to the judgment in Study 1 that this token of KITE showed decreased iconicity vis-à-vis the adult target.

2. Hypothesis 2: We hypothesized that, if joint activity is omitted from a sign that involves action at two or more joints in the adult target, children will tend to omit the more distal articulation. Inspection of our database revealed 55 such instances of omission of action at a joint.\(^{11}\) The preponderance were produced by Caitlin ($n=22$) and Noel ($n=20$); Susie and Katie respectively produced four and nine errors of this type. With just two exceptions from Katie, all instances of this error type involved the omission of action at the more distal joint. For example, Noel produced the sign GRAPE at 1;4,6. In the adult, this sign is typically produced with movement at the wrist and shoulder. In her production of this sign wrist movement was omitted; only shoulder movement was retained.

3. Hypothesis 3: Lastly, we hypothesized that, if a child added action at an unexpected joint to a sign, the added joint would be proximal to the target joints. For the purposes of this analysis, proximal and distal additions are respectively defined with respect to the most proximal or distal joints that the child preserved from the target form.\(^{12}\) We identified 78 addition

---

\(^{11}\) In 8 instances, a child omitted the two more distal joints from a target sign that has three joints in the adult language.

\(^{12}\) Some addition errors could not be considered in this analysis, inasmuch as the added joint was in between two joints used by the child, one more proximal and the other more distal.
errors. One child (Caitlin) produced none. The data from the other subjects were not consistent with our hypothesis: in 30 errors, a child added a proximal joint, but in 48 a distal joint was added.

On inspection, we found that many of the addition errors arose from an apparent linkage in children’s productions between the first and second knuckles (K1 & K2). The preponderance of the distal additions (43 of 48 tokens) involved the most distal joint, K2. In these 43 instances in which K2 was added (Caitlin 0, Katie 11, Noel 13, Susie 19), all had K1 as a target joint; K2 was never added without concurrent articulation at K1. An example is Susie’s articulation of the sign DOG at 0;9,10 and later. Instead of the repeated bending of the middle finger that is characteristic of the adult sign used by the mother, she produced a closing movement of all five fingers at both K1 and K2; the result was a form that could readily be confused with her rendition of the noun MILK. If K2 is excluded from our analysis of addition errors, we find 30 proximal additions (86%) and 5 distal additions (14%), distributed as follows over the four children: Caitlin (0 proximal, 0 distal); Katie (9 proximal, 2 distal, \( p < .05 \) by the binomial test); Noel (1 proximal, 0 distal); and Susie (20 proximal, 3 distal, \( p < .01 \)).

Discussion

Does a single articulator predominate in infant sign production, as has been suggested in work on infant speech development? The subjects in this study showed relatively effective control of the shoulder, elbow, and first knuckles, but control of the forearm and wrist was poor. Control of the shoulder and elbow is consistent with infant reaching abilities. Early control of articulation at the first knuckles, and the tendency to add unexpected articulation at the second knuckles, is consistent with an infant ability to grasp objects. This result is also consistent with reports that signing infants control simple open-close movements of the hand (Bonvillian & Seidlecki, 1998; Cheek et al., 2001; Petitto, 1988; Petitto & Marentette, 1991).  

An Analysis of the Adult Vocabulary

In a follow-up study we examined joint usage in an independently-compiled sample of ASL signs. With the assistance of a fluent Deaf signer and teacher of

---

13The linkage noted here between K1 and K2 is also consistent with the observation in Cheek et al. (2001) that these same children tended to substitute open-close movements of the hand for the wiggling movement expected in the signs COLOR and DIRTY. The children produced no tokens of wiggling, although 35 opportunities to do so were identified. In the adult language, wiggling is restricted to K1; a possible substitute would have been a repeated bending of all four fingers at K1, as in the sign EXPECT. This substitution was not encountered by Cheek et al.
ASL, we coded joint usage in 213 signs illustrated in the first five chapters of an introductory ASL textbook that has high-quality line drawings (Humphries, Padden, & O’Rourke, 1980, *A Basic Course in American Sign Language*, henceforth “ABC”). By coding signs from this text, we examined a set of basic ASL signs.

In Figure 4, we compare joint targets in the ABC sample with joint targets in the adult signs that the children attempted; here we consider sign types, not the frequency with which a given sign was produced. In both samples of the ASL lexicon, the elbow is well-represented, strikingly so in the ABC sample. In the ABC sample, the other six coding categories each constituted 5–15% of the target joints. In the children’s targets, both the elbow and shoulder twist are well-represented. The strong representation of the elbow in the adult vocabulary—and in the children’s target signs—may contribute to its early, successful usage by children. However, the joint category on which children were most accurate was K1 (see Table 2); yet this category is much more modestly represented in the ABC sample and in the children’s targets. The early success shown by three of our four subjects on K1 cannot be attributed to disproportionate representation in the adult vocabulary. By the same logic, children’s poor performance on signs with forearm twist (again see Table 2) cannot be attributed to under-representation of this movement type in the adult vocabulary. Lastly, we examined whether K1 and K2 are linked in the adult vocabulary. The children attempted no target signs that, on our coding,
required action at both joints, yet those children added K2 articulation to 48% of the 98 tokens where K1 was a target and was successfully used. In the ABC sample, 29 signs call for K1 and 17 for K2, but only 6 (i.e., 21% of K1 targets) called for both K1 and K2 (e.g., the sign UNDERSTAND, in which a closed handshape changes to one in which the index finger is fully extended). Properties of the adult vocabulary do not support the K1/K2 linkage found in children’s signing.

Proximalization

When infants err in the production of sign movement, they tend to proximalize. In most substitutions, the child erred by using a more proximal articulator than the target. In the smaller pool of omission errors, the children omitted a more distal articulator, rather than a more proximal one. The analysis of addition errors revealed an unexpected class of distalization errors arising from the apparent infant tendency to link articulation at K1 and K2. Otherwise, children’s addition errors revealed a tendency to add a relatively proximal articulator rather than a distal one. Proximalization errors are not restricted to ASL, but also occur in the acquisition of Quebec and Finnish Sign Languages (Lavoie & Villeneuve, 1999; Takkinen, 2003; as reviewed in Meier, 2006).

While the major factor pushing infants to proximalize sign movement may be motoric, input factors may also contribute. Enlarged signs are a feature of the child-directed signing of Deaf mothers. Launer (1982, p 156) indicated that enlarged maternal signs “often changed the primary source of movement from one joint or muscle group to the next adjacent one, resulting in gross movements rather than fine movements.” Holzrichter and Meier (2000) reported instances in which the enlargement of signs was achieved through the addition of a proximal articulator not expected in adult-directed signing. For example, the citation-form sign RED has a repeated bending of the index finger at the second knuckle. In 8 of 17 child-directed tokens of RED in their sample, the parent produced a path movement articulated at the elbow or shoulder, simultaneous with the bending movement at K2. Confronted with a similar version of RED produced by her Deaf uncle (who was also an experimenter), Katie (1;4,3) greatly enlarged the to-fro movement at the elbow of the adult model, but entirely omitted the distal, hand-internal movement at K2. Input factors might contribute to children’s proximalization in the following way: Proximalized variants of signs may be visually more salient than citation forms (Brentari, 1998). As a consequence, movements of proximal articulators may be better represented by children than movements of distal articulators.

Informal examination of the linguistic contexts surrounding some of the signs in our database indicates that there are frequent examples of parent-child
conversations in which a child’s sign is proximalized by comparison to the parent’s articulation of that same sign in the same conversation. In a conversation in which Caitlin (0;11,3) and her mother were looking at picture books, Caitlin produced the sign MOUSE. In the adult language, this sign has an index handshape (index finger extended, other fingers and thumb fist) with the palm oriented to the contralateral (i.e., nondominant) side; the side of the extended finger repeatedly brushes the tip of the signer’s nose. In Caitlin’s unprompted use of this sign, the movement of the hand past the nose was driven at the shoulder. In contrast, the mother’s subsequent articulation of MOUSE was distalized; movement was restricted to a repeated bending of the extended index finger at K1. The mother did not model the shoulder movement employed by her daughter.

Lastly, parents and children sometimes proximalize in different ways. When parents proximalize, they preserve the overall shape of the sign. For example, the sign BLACK is generally produced with an inward twisting movement of the forearm; the tip of the extended index is thereby drawn across the forehead. This sign may be proximalized, and thus enlarged, by using the shoulder to pull the entire arm to the side. In contrast, children’s proximalizations may grossly distort a sign’s shape. For example, Noel (0;11,7) articulated BLACK by raising the arm at the shoulder, thereby moving the hand back over the head rather than across the forehead.

In sum, our view is that input factors are unlikely to be the sole cause of the proximalization errors in our data. Further support for this view comes from a study of how naïve hearing adults from the U.S. and Germany imitated signs drawn either from ASL or German Sign Language (Mirus et al., 2001). Subjects saw a single videotaped rendition of each sign. An analysis of their imitations revealed that proximalization of movement was frequent, but not distalization. Even Deaf signers showed some tendency to proximalize in their imitations of signs drawn from a foreign sign language. Deaf Germans proximalized approximately 9% of the ASL stimuli that they were asked to imitate, whereas distalizations were exceedingly rare. The relatively high frequency of proximalizations produced by the naïve hearing subjects is consistent with the suggestion that proximalization of movement is typical during the acquisition of new motor skills. The results also suggest that proximalization of sign movement is not due simply to subjects’ having better memories for more salient, proximalized variants, inasmuch as the subjects in Mirus et al. viewed only a single form of each stimulus item.

GENERAL DISCUSSION

Because of the potential of the visual-gestural modality for iconic representation, the ways in which children produce ASL signs could be guided by one or both of
two factors explored here: 1) by an attempt to enhance the motivation of signs, or 2) by the constraints of an immature motor system. Although iconicity may contribute to the early use of onomatopoetic words such as *meow* or *moo*, iconicity in spoken languages is generally too infrequent to have a major effect on early vocabulary development. In contrast, iconic signs are relatively frequent in adult ASL. Nonetheless, we find little evidence that children systematically err by seeking to enhance the iconicity of signs. The infants observed here made little overt use of the pictorial resources of the visual-gestural modality. In the future, more fine-grained analyses than those reported here might probe the possibility that young signing children enhance the iconicity of particular classes of signs; however, our data provide scant cause for optimism about such analyses, at least when the data come from signers as young as ours. Remember that our subjects showed no tendency to produce the more iconic, two-handed variants of signs such as *cat*. Recent work has raised the possibility that the situation may differ for somewhat older children: such children may use certain highly iconic forms early (cf. the discussion of classifiers in Slobin et al., 2003) or first (cf. the discussion of verb agreement in Casey, 2003). However, older children also produce error types that obscure the motivation of some of the most transparently iconic signs of ASL (Meier, 1982, 1987; Supalla, 1982).

Our results are consistent with the claim that motoric factors—not iconic ones—constrain children’s early sign production. Having said this, we acknowledge that we have yet to systematically assess the relative contributions of motoric factors versus input factors in promoting the effects we have observed. In the input they provide, Deaf parents sometimes enlarge signs by proximalizing movement; they also sometimes add movement cycles, perhaps so that signs are noticed by children. Yet, language learners produce repetitive and/or proximalized movement in situations (e.g., infant reduplicative vocal babbling; adult imitation of signs) in which they cannot be closely matching features of the linguistic input. Evaluating the extent to which children are matching input properties in their use of repetition and of proximalization will depend on analysis of grammatical patterns in adult ASL, along with close attention to the forms that parents actually use in conversation with their children. In the future, we plan detailed comparisons of children’s productions to the forms their parent’s model.

In contrast to the phenomena reported here, motoric factors may have little role in other aspects of phonological development in signed languages. Consider children’s acquisition of place of articulation, as opposed to their acquisition of handshape. Children make relatively few errors in place of articulation, even from the very outset of the one-word period, whereas their acquisition of handshape appears to be long and error-filled (Cheek et al., 2001; Juncos et al., 1997; Karnopp, 2002; Marentette & Mayberry, 2000; Siedlecki & Bonvillian, 1993).

Here we have focused on two motoric factors derived from the literature on general motor development in infants. One of these trends is shared by the oral
and manual modalities; a tendency toward repetitive, cyclic motor behaviors is not only manifest in sign, but also in such speech phenomena as reduplicative babbling and place harmony (e.g., [gagi] for ‘doggie’). The other motoric factor pertains only to signed languages. Not surprisingly, signed and spoken languages may be subject in development to different (but not disjoint) sets of articulatory constraints. For both language types, the constraints of immature articulatory systems are important determinants of the form of children’s earliest lexical items. In sign, those articulatory constraints mean that children’s signs are often less iconic than their adult counterparts.

Our focus on motoric constraints on early sign production has been productive. Although alternative explanations involving input and/or perceptual factors must be explored further, our data have proved consistent with motoric explanations that draw independent support from research on nonlinguistic motor development. In testing the hypotheses proposed here, we have uncovered unexpected patterns, such as the class of distalization errors associated with an apparent linkage in early motor control between the first and second knuckles. That linkage may be associated with the early ability of infants to grasp objects.

In testing the proximalization hypothesis, we undertook a detailed analysis of the articulators used in early sign production. The results of that analysis suggest that signing children may not be constrained in some of the ways that their speaking counterparts are. In analyses of early speech development, MacNeilage and Davis (1993) have claimed that oscillation of the mandible is the “frame” by which infant and adult syllables are organized. On their account, the speaking infant—especially, the babbler—is largely limited to a single oscillator and has limited capacity to vary tongue position within a syllabic frame, or even across syllables. Accordingly, syllables such as [di] in which consonant and vowel are both produced with a fronted tongue are favored in babbling and early speech, whereas syllables such as [du] that demand a change from a fronted to a backed tongue position within a single open-close cycle of the mandible are disfavored.

We see little evidence that there is a single oscillator that underpins the syllables of adult signed languages; note again the varying articulators engaged by the signs in Figure 3. In signing, three oscillators seem to be available in infancy—the shoulder, elbow, and first knuckles. In particular, infant control of articulation at the first knuckles and at the elbow appear to be independent, so that at 1;1,

14Articulatory “undershoot” is another example of a motoric phenomenon common in speech articulation (Lindblom, 1990) that may also be characteristic of the production of signed languages. In rapid speech, the oral articulators may fail to reach phonologically-specified targets; the same occurs in sign (Mauk, Lindblom, & Meier, in press).

15For recent discussions of the notion of a sign syllable, see Brentari (1998) and Sandler and Lillo-Martin (2006). These authors review evidence suggesting that certain constraints on the well-formedness of signs must refer to syllables, rather than whole signs or morphemes.
Susie successfully produced signs that entail movement at the elbow (e.g., FATHER) without intruding action at the first knuckles and she produced signs at the first knuckles (e.g., BIRD) without intruding action at the elbow. In contrast, control of the tongue is—on the view of MacNeilage and Davis (1993)—strongly linked to mandibular oscillation in the speaking infant. In this sense, signing infants may have more independent articulators available to them in early language development than do speaking infants. Further work—across a longer span of development than we probed here—may reveal whether early differences in how infants articulate signs versus words have lasting effects on the organization and acquisition of signed versus spoken languages.

The findings reported here have important implications for our understanding of the phonology of early signing. For the speaking child, the syllable appears as a contrast between a closed and open vocal tract; that contrast is executed by movement of the mandible from a raised position to a lowered one. With development, children can vary consonant and vowel by controlling tongue position within and across mandibular oscillations. For the signing infant, two or more articulatorily- and visually-distinct syllable types are available. One involves articulation at a proximal articulator; action at the elbow results in the movement of the hand through space (so-called “path movement”). Signs such as MOTHER, FATHER, SEE, and GIVE use the elbow as an articulator. The other syllable-type involves action at the first knuckles, resulting in a hand-internal movement. A large number of signs have hand-internal movement at the first knuckles; these include MILK, ORANGE, BOY, DIRTY, HORSE, and COLOR. Many of these are signs that children are likely to learn early. These two movement types—path movements and hand-internal movements—are also employed by 3- and 4-year old deaf children who have innovated their own home sign systems (Goldin-Meadow, Mylander, & Franklin, 2007). This finding suggests that children’s use of both path and hand-internal movements in early signing may not depend on the availability of input from a conventional linguistic model.

In sum, the articulators in sign and speech place different demands upon the child, and offer different resources to that child. In their production of signs, 

\[\text{In hypothesizing the independence of articulation at these two joints, we are considering only the lexical movements of signs. If we also consider “transition” movements into signs (see for example, Liddell, 1984), then there is a sense in which articulation at K1 does, in fact, depend on articulation at proximal articulators of the arm. The child must flex her arm at the elbow in order to bring her hand into the signing space, or may have to raise her arm from the shoulder to achieve the appropriate place of articulation. There is no evidence that these actions should be specified as part of the lexical entry for any sign. If children failed to execute the movements necessary to bring the hand into the signing space, a gross place of articulation error would ensue, with the hands dangling below the child’s waist. We have encountered only one instance of a gesture that could plausibly be described in this way (Conlin et al., 2000: 64).}\]
infants through 18 months make relatively little use of the resources for iconicity that the visual-gestural modality offers. But these infants do exploit the articulatory resources of this modality. Infants have the motor control necessary to achieve generally correct place of articulation in sign. Early in development, a number of distinct places of articulation are typically expressed correctly. Another resource available to signing infants lies in the varied oscillators that they control. If we are right that signing infants have effective control over three oscillators, in addition to the motor control necessary to target different places of articulation on their body, then signing infants have two relatively reliable mechanisms whereby they can signal lexical contrasts (even when other articulatory parameters, such as handshape, are not well controlled). There have been conflicting claims as to whether first signs (or perhaps the first gestures of signing and speaking children) are earlier to appear in infancy than first words (Anderson & Reilly, 2002; Meier & Newport, 1990; Orlansky & Bonvillian, 1985; Petitto, 1988; Volterra & Iverson, 1995). Newport and Meier (1985) speculated that an apparent lag in the emergence of first words relative to first signs might reflect better early control of the manual articulators than of the oral ones, or it might be due to early signs being better recognized by adult observers than early words. Children’s early success at place of articulation in sign, and the early availability of proximal and distal articulators, could permit children’s clumsy attempts at articulating signs to be better recognized by parents than are the first words of speaking children. To test such speculations, further research comparing speech and sign development is necessary in order to understand the contribution that articulatory factors make to the timing and progress of language development.

AUTHOR NOTE

This project was supported in part by a Special Research Grant from the University of Texas at Austin. Preliminary versions of this research were reported at the Stanford Child Language Research Forum and at the Boston University Conference on Language Development. The analyses reported in Study 3 are based on Chris Moreland’s undergraduate honors thesis; his research was supported by an Undergraduate Research Fellowship from The University of Texas at Austin. He is now at the Division of Internal Medicine, University of California, Davis. We thank Ashley Roberts, Perry Connolly, and MaryJean Shahen for their assistance in the research reported here. Lastly, we thank Christian Rathmann, Gary Morgan, and Jilly Kowalsky for their comments on an earlier draft of this paper. Address for correspondence: Richard P. Meier, Department of Linguistics, University of Texas at Austin, 1 University Station B5100, Austin, TX 78712 or meier@mail.utexas.edu.
REFERENCES


MEIER, MAUK, CHEEK, AND MORELAND


Emmorey (Ed.), *Perspectives on classifier constructions in sign languages* (pp. 271–296). Mahwah, NJ: Erlbaum.


