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The development of iconicity in children's co-speech gesture and homesign

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Abstract

Gesture can illustrate objects and events in the world by iconically reproducing elements of those objects and events. Children do not begin to express ideas iconically, however, until after they have begun to use conventional forms. In this paper, we investigate how children's use of iconic resources in gesture relates to the developing structure of their communicative systems. Using longitudinal video corpora, we compare the emergence of manual iconicity in hearing children who are learning a spoken language (co-speech gesture) to the emergence of manual iconicity in a deaf child who is creating a manual system of communication (homesign). We focus on one particular element of iconic gesture – the shape of the hand (handshape). We ask how handshape is used as an iconic resource in 1–5-year-olds, and how it relates to the semantic content of children's communicative acts. We find that patterns of handshape development are broadly similar between co-speech gesture and homesign, suggesting that the building blocks underlying children's ability to iconically map manual forms to meaning are shared across different communicative systems: those where gesture is produced alongside speech, and those where gesture is the primary mode of communication.

1. Introduction

Gesture is ubiquitous in human communication and plays a particularly important role in early childhood. Children point before they can speak and learn a rich set of manual conventions (like nodding, shrugging, and begging with an outstretched hand) to communicate with those around them. Iconicity in gesture is a powerful tool for conveying information by producing shapes or movements that echo and thus illustrate features of objects or events in the world (e.g. flapping hands at sides to represent a bird's wings). Little is known, however, about how the developmental trajectory of such gestural iconicity relates to communicative development more broadly. In children's gestural communication,

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iconicity develops later than other semiotic forms, such as indexes (e.g. pointing or hold-up gestures) and symbols (i.e. conventionalized gestures, Iverson, Capirci, & Caselli, 1994; Özçalışkan & Goldin-Meadow, 2005). This developmental pattern is somewhat counterintuitive – since using iconic gestures does not rely exclusively on knowledge of pre-existing communicative conventions, iconic gestures might seem like they would be simple for young children to produce and comprehend. Iconic gestures, by definition, are visually similar to their referents, and thus have the potential to provide insight into their meanings without prior knowledge of form-to-world mappings. For example, understanding the meaning of a conventional gesture like the "OK" sign requires knowing the culturally agreed-upon meaning of that form. However, understanding the meaning behind two fingers bent into a circle to represent a round object instead rests on the ability to notice and interpret similarity between the form of the body and the referent. Noticing this similarity is not a trivial process, however, as it involves abstraction and analogical reasoning (Calbris, 2011).

In this work, we ask how children's use of manual iconicity develops when gesture *complements* a conventional linguistic system (in co-speech gesture) versus how it develops when gesture *comprises* the core of a communicative system (in the homesign systems that deaf children create when not exposed to conventional sign languages). The communicative systems of these children differ dramatically: for hearing children, gestures complement the structure and complexity found in speech, whereas for homesigners, linguistic structure emerges in the manual modality itself (Goldin-Meadow & Mylander, 1984; Goldin-Meadow, 2003; Goldin-Meadow, 2014). The co-speech gestures of hearing children, when taken on their own, thus display far less linguistic structure than homesign. The fact that gesture's intelligibility is always critical to successful communication in homesign, but is critical only on occasion in co-speech gesture, likely places different pressures on the development of gesture as an effective communicative medium (see Meier, Mauk, Cheek, & Moreland, 2008).

Although we know that homesign displays more linguistic structure than co-speech gesture, we know little about the individual gestures that young homesigners use, compared to those used by young co-speech gesturers. In particular, we do not know whether these two groups of children exploit iconicity in the same way. If the ability to understand and use iconic mappings between the hand and the world is closely tied to the language a child is developing (a conventional language for co-speech gesturers versus a self-generated language for homesigners), then we might expect iconicity to emerge at different speeds or in different ways in the two groups of children. If, however, the ability to exploit iconic mappings between hand and world depends on general cognitive developmental processes, we might expect more similarities than differences between the two groups in how iconicity is used in individual gestures. Iconicity has been observed in both co-speech gesture and homesign, but the development of this way of referencing the world has not (to our knowledge) been directly compared. Here, we explore the early development of manual iconicity in hearing children learning English and a deaf child generating homesign.

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1.1 Iconicity in co-speech gesture

Iconic gestures illustrate features of their referents using some combination of handshape, movement, and location information.[1] For example, a person might gesture about throwing a ball by holding her hand in a curved open shape (handshape) and projecting it in a forward arc (movement) from the shoulder out away from the body (location). Handshape has the potential to express different types of gesture-to-world mappings. The hands may be used mimetically to represent hands acting on an invisible world (e.g. moving a fist in the air as though swinging an imaginary tennis racket) – a '*hand-as-hand*' handshape. The hands may also be used to depict an object's shape (e.g. swinging a flattened hand in the air illustrating the flat shape of the racket as it is swung) – a '*hand-as-object*' handshape. Finally, the hands may take neutral forms, such that the iconic mapping of the gesture is conveyed entirely through movement and location (e.g. using an index finger to draw the outline of a tennis racket or trace the trajectory of a tennis ball) – a '*hand-as-neutral*' handshape.

These handshape distinctions resemble, but are not identical to, the viewpoint categories described by McNeill (1992), character viewpoint (first person) versus observer viewpoint (third person). Character viewpoint typically involves *hand-as-hand* depictions, whereas observer viewpoint tends to involve *hand-as-object* or *neutral* depictions. However, there are instances where the gesture is located in space using the body as a frame of reference in a way that suggests a character viewpoint but the handshape is hand-as-object or neutral. For example, the hand may be placed flat on top of the head in a gesture representing a hat. Here, the hand represents the object (hand-as-hand), but it uses a character viewpoint. For the analyses presented here, we chose to focus on the shape of the hand rather than viewpoint, although the two are often in alignment.

Gesture is an important communicative modality in early childhood for hearing children learning a spoken language. In terms of gesture production, children point before they can speak, and begin using conventional gestures (like head shakes and open palm requests) during their first year of life (Bates, 1976; Bates et al., 1979). Research on hearing children's early gesture production suggests that iconic gestures are quite rare and emerge late in development relative to other gesture types (Iverson, Capirci, & Caselli, 1994; Nicoladis, Mayberry, & Genesee, 1999; Özçalışkan & Goldin-Meadow, 2005). Children occasionally produce iconic gestures in the first 2 years of life, but undergo a growth spurt in their use of these gestures just after 2 years of age (Özçalışkan & Goldin-Meadow, 2011). Some argue that iconic gesture production before the age of 2 may not involve an understanding of the mapping between body and referent, but rather results from reproducing routines (e.g. games like itsy-bitsy spider, Acredolo & Goodwyn, 1985, 1988). In terms of gesture comprehension, at approximately age 2, children can interpret an iconic gesture as a label for an entity (Namy, Campbell, & Tomasello, 2004; Namy, 2008) or for an action (Goodrich & Hudson Kam, 2009; Marentette & Nicoladis, 2011), and can use iconic gestures produced

[1]Iconicity is not a monolithic property: features of a gesture may vary in the degree to which they resemble aspects of real world entities or events. There are levels or shades of iconicity and, more importantly, the features that bear an iconic relationship to a referent differ from gesture to gesture. A gesture can represent many features of its referent or only a single feature. For example, a gesture referring to a helicopter flying by could use a twirling motion with one finger, overhead, moving along a particular path. However, a gesture could also reference the event by conveying only one feature (say, the path through which the helicopter flew, or the twirling motion of the blades).

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by others to figure out the function of a novel toy (Novack, Goldin-Meadow, & Woodward, 2015). However, in many cases, children fail to robustly interpret others' iconic gestures until ages 3 or 4, particularly when the gestures represent features of an entity, rather than an action (Stanfield, Williamson, & Özçalışkan, 2014; Tolar, Lederberg, Gokhale, & Tomasello, 2008).

Much of the research on children's early iconic gesture production has largely focused on the dichotomy between hand-as-hand vs. hand-as-object gestures to depict instrumental actions in elicitation paradigms (Overton & Jackson, 1973; Boyatzis & Watson, 1993; Mitchell & Clark, 2014; Mizuguchi & Sugai, 2002). In these tasks, children are asked to show researchers how they would perform a particular action (e.g. brushing hair) in the absence of any physical tools. The children gesture their response, using either a hand-as-hand gesture depicting an "invisible" object, or a hand-as-object gesture where the hand stands in for the missing object. These studies typically find that younger children (3–4 year olds) use more hand-as-object gestures, whereas older children (6–8 year olds) start to prefer hand-as-hand gestures. The early hand-as-object bias they report may be an artifact of the task or of the particular types of referents used in the task. When children's production of hand-as-hand and hand-as-object co-speech gestures is studied in more spontaneous conversation, there is no early preference for hand-as-object gestures (Cartmill, Novack, Loftus, & Goldin-Meadow, in preparation; Marentette et al., 2016). In addition, studies have found that children's production of specific representational gestures is preceded by production of the corresponding action (e.g. a child holding a toy phone to her ear precedes gesturing about talking on the phone). This finding suggests a continuity from physical action to representational gesture (Capirci, Contaldo, Caselli, & Volterra, 2005; Pettenati, Stefanini, & Volterra, 2009; see also Caselli, Rinaldi, Stefanini, & Volterra, 2012).

1.2 Iconicity in homesign

Iconic gesture plays an even more important role in the communication of children who are profoundly deaf from birth and are not exposed to sign language. These children develop their own idiosyncratic gestural communication systems, referred to as *homesign* (Goldin-Meadow, 2003; Goldin-Meadow & Mylander, 1984). Homesign is a manual system that contains many, but not all, of the structural properties found in natural language, including conventional signed languages used in deaf communities. For example, children's homesign systems have been found to contain displaced reference (Butcher, Mylander, & Goldin-Meadow, 1991), consistent word order (Feldman, Goldin-Meadow, & Gleitman, 1978), argument structure (Goldin-Meadow & Mylander, 1984, 1998; Goldin-Meadow, Butcher, Mylander, & Dodge, 1994), negation (Franklin, Giannakidou, & Goldin-Meadow, 2011), causation (Rissman & Goldin-Meadow, in press), and distinctions between nouns and verbs (Goldin-Meadow et al., 1994). Critically, children seem to be generating these properties themselves rather than learning them from the environment that surrounds them since the properties are not found in the co-speech gestures of their families, and the children have had no contact with signed languages (Goldin-Meadow et al., 1994, 1998; Goldin-Meadow, Franklin, & Mylander, 2007; Hunsicker & Goldin-Meadow, 2012). Although the structures and uses of homesign differ dramatically from the co-speech gestures of hearing children, the emergence and use of iconic elements in homesign may share commonalities with the

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emergence and use of these same elements in co-speech gesture. We explore this possibility here.

Previous studies have compared handshape use across homesign and co-speech gesture, but our work is the first to do so through a developmental lens. We focus on handshape because this feature is grammaticalized in established sign languages, thus demonstrating that handshape has the potential to manifest linguistic structure. For example, in established signed languages in deaf communities, handshape is treated as a categorical rather than a continuous variable (Emmorey & Herzig, 2003; Emmorey et al., 2003) and encodes both morphosyn-tactic and morphophonological features (Benedicto & Brentari, 2004; Padden, Meir, Hwang, & Lepic, 2013; Brentari, Di Renzo, Keane, & Volterra, 2015).

This paper presents four comparisons of iconic development in co-speech gesture and homesign: (1) overall frequency of iconic gesture, (2) relative frequency of handshape type (hand-as-hand, hand-as-object, hand-as-neutral), (3) handshape type when referencing entities (akin to nouns) vs. actions (akin to verbs), and (4) handshape type when referencing actions performed on an object (akin to transitive actions) vs. actions performed without an object (akin to intransitive actions). These comparisons are hierarchically ordered – each subdividing one or more categories used in the preceding analysis. Iconic gesture use can be broken down into entities and actions; actions can be further classified as actions-on-objects or actions-without-objects. We included the classification of actions-on-objects and actions-without-objects because we suspected that handshape types might be used in different ways with these different types of actions.

We chose entities and actions as our main semantic categories within which to examine the relation between handshape use and meaning because distinguishing between labels for entities (nouns) and labels for actions (verbs) is a core property of language, present in all known languages (e.g. Sapir, 1921; Givon, 1979; Hawkins, 1988; Hopper & Thompson, 1984; Schachter, 1985), including established sign languages (Supalla & Newport, 1978). Nouns are also distinguished from verbs in homesign (Goldin-Meadow et al., 1994), but the way in which they are marked changes over development (Hunsicker & Goldin-Meadow, 2013). We use the more generic terms *entity* and *action* rather than *noun* and *verb* because there is no evidence that these categories are grammatical in co-speech gestures in the way that they are in homesign (Goldin-Meadow et al., 1994).

Hunsicker and Goldin-Meadow (2013) found that one homesigning boy (David, the same child we analyze here) used *handshape* to differentiate nouns from verbs, but only before he developed other ways of marking these categories. Starting at 3 years 5 months (41 months), David began to use other morphological features to mark nouns and verbs (Goldin-Meadow et al., 1994; Hunsicker & Goldin-Meadow, 2013). He “abbreviated” his gestures when they served as nouns, repeating movements fewer times than when the same gesture was used as a verb. He also began to inflect verb gestures by displacing them in space towards relevant objects. For example, he would produce a twisting gesture near a jar to indicate opening, but produce the same gesture in front of his body to reference the jar (Goldin-Meadow et al., 1994). Hunsicker and Goldin-Meadow (2013) and Haviland (2013) argue that handshape is not a robust enough feature to serve as the primary designation of nouns and verbs. Thus,

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once other techniques for differentiating nouns from verbs arose in the emerging communication system, handshape was no longer used as a grammatical tool for marking the distinction between nouns and verbs. Handshape does re-emerge, however, as a grammatical marker for David: Rissman and Goldin-Meadow (in press) found that, after age 4;11, David uses hand-as-hand handshape to encode causation.

These studies demonstrate that when gesture takes on the full burden of communication, as it does in homesign, iconic features like handshape can develop abstract grammatical functions. Co-speech gesture is not subject to the same pressures, as children learning spoken language have access to a productive grammatical system through their spoken language. Despite these different pressures, however, we do not know whether the fundamental ability to iconically map the form of the hand to referents in the world emerges differently in these two language environments. If the ability to use manual iconicity as a semiotic tool is subject to general processes of cognitive development, we might see broad similarities across homesign and co-speech gesture with respect to the initial emergence of handshape types, the distribution of handshape types for actions vs. entities, and for actions-on-objects and actions-without-objects. If, however, the communicative burden of gesture strongly constrains the development of gestural iconicity, we would expect significant asymmetries in the emergence and use of iconic features between homesign and co-speech gesture.

2. Methods: co-speech gesture

2.1 Participants

Participants were drawn from a larger longitudinal study of language development conducted at the University of Chicago (described in more detail in Goldin-Meadow et al., 2014; Özçaliskan & Goldin-Meadow, 2009; Rowe & Goldin-Meadow, 2009). Our sample consisted of 52 children (25 girls, 27 boys) selected from the 63 children enrolled in the larger study. The children we chose for this study were those who remained in the longitudinal study from 14–50 months and who had produced at least one iconic gesture before the age of 50 months. All children were from the Chicago area and were being raised as monolingual English speakers. Families were chosen to participate in the longitudinal study to reflect the demographic and socioeconomic makeup of the area; there was substantial diversity in race, ethnicity, and socio-economic status. Family incomes ranged from less than $15,000 to over $100,000 per year. Education of the primary caregiver ranged from 10 years (some high school) to 20 years (advanced degree).

2.2 Data collection

Children were videotaped in their homes every four months between the ages of 14 months and 58 months. At each home visit, a research assistant followed the children with a video camera for 90 minutes as the children went about their day. Parents were told that the focus of the study was on language development, and were asked to go about their normal daily routine as if the camera person were not there. The video corpus includes a wide range of daily activities, from playing games, reading books and getting ready for bed, to family

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gatherings, outings, craft making, and mealtimes. For the data reported here, we analyzed video from the first 10 home visits (14–50 months of age).

2.3 Gesture coding

Trained coders transcribed all of the speech and gesture produced by the focal children during the 90-minute observation sessions. Coding was a multi-year process involving many different coders and coding passes on the video. Speech and basic gesture categories were coded first. Extra details of the iconic gestures were added later. Some coding was done specifically for this project. Reliability is addressed below. Hand movements were classified as gestures if they were communicative and did not involve ritualized games or songs (e.g. itsy-bitsy spider) or the functional manipulation of physical objects (e.g. putting on a watch). Coders recorded when gestures occurred and categorized them into one of 4 types: *deictic*, *conventional*, *emphatic*, or *representational* (these coding categories were defined by McNeill, 1992, and their use by children is described in greater detail in Cartmill, Demir, & Goldin-Meadow, 2011). We focus on iconic representational gestures, that is, gestures that have at least one feature that transparently maps onto the gesture's reference; for example, index finger and thumb pinched together to illustrate holding the string of a balloon. Metaphoric gestures (e.g. a cupped hand to represent an abstract idea) are also considered to be representational gestures, but young children produce very few of these gestures and we did not include them in this analysis.

We extracted all iconic gestures from the transcripts along with the speech that accompanied those gestures. The gestures were then coded for *handshape*, and the gesture meanings were coded as referencing actions or entities. Action gestures were then further coded as actions-on-objects and actions-without-objects. For example, for a gesture in which a child dangles her fingers downward and wiggles them to represent a spider, the handshape would be coded as hand-as-object, the referent would be coded as entity, and action on/without object would be coded as not applicable. This coding process is described in the following sections.

2.3.1 Handshape—We categorized each gesture according to the relation between the form of the hand and features of the object in the world that the gesture represents. The three codes that we used were based on hand form. When available, accompanying speech was used to disambiguate the referent of the gesture (e.g. if a child extended his arm while making a grabbing gesture, we would typically code handshape as representing a hand, but if he said "digger scooped it up" while making the same gesture, we would code handshape as representing an object, the digger, rather than a hand).

1. *Hand-as-Hand* codes were applied to gestures in which the hand represented a hand acting on an imagined world. For example, a cupped hand used in a throwing motion to represent throwing a ball would be considered a hand-as-hand handshape. We also coded gestures in which the hands were used to represent the arms or wings of an animal performing an action on an object as hand-as-hand gestures (i.e. the "hands" represented did not have to be human hands). Thus, if a child flapped his arms like wings and said "like a bat," the handshape would be coded as hand-as-hand.

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2. *Hand-as-Object* codes were applied to gestures in which the hand depicted the shape of an object or entity. For example, pointing two fingers downward while wiggling them to represent a person walking would be considered a hand-as-object handshape. A hand held flat and flipped over to represent a spatula flipping something would also be coded as hand-as-object.

3. *Hand-as-Neutral* codes were applied to gestures in which the shape of the hand itself did not represent any features of the referent. In these gestures, it is the movement alone (rather than handshape plus movement) that maps onto the referent. The hand is typically held in a pointing configuration or held loosely with an open flat palm, and then used to 'trace' the shape of an object or the path of an action. For example, tracing a circle in the air with an extended index finger to represent the path of a toy train (but not any feature of the train itself) would be considered a neutral handshape. Neutral handshapes that were used to demarcate distances in conventional ways (e.g. the hands held shoulder-width apart to represent the size of a fish) were termed "boundary gestures" and were not coded in this analysis.[2]

2.3.2 Referent—Each gesture was coded as referring to either an entity (e.g. a kite) or an action (e.g. sliding down). This coding was done using gesture form, conversational context, and any accompanying speech. A gesture depicting an event involving both an action and an entity, like blowing up a balloon (depicted by pinching the index finger and thumb together in front of the mouth and blowing) could be used to refer either to the balloon being inflated (an entity) or to the act of inflating (an action). The speech that accompanied the gesture was often used to disambiguate these cases. For example, if a child said, "you have to do it like this," while producing the balloon-inflating gesture, it would be coded as an action. If the child said, "I want to get a balloon," the gesture would be coded as an entity. If there was no speech or the child speech was ambiguous, the referent was coded either as uncodable, or a best guess was made based on the communicative context and the parent's interpretation within the scene. Gestures that referred to physical attributes of entities (e.g. the roundness of a toy) were typically categorized as being about entities. This differed from the homesign coding where some attribute gestures would likely be coded as adjectives.

2.3.3 Actions-on-objects and actions-without-objects—Gestures that referred to actions were further coded according to whether the action represented was performed on an object (typically encoded by transitive verbs) or without an object (encoded by an intransitive verb). Actions-on-objects included actions like opening, mailing, hammering, eating, pinching, putting on, driving, ripping, and digging. Actions-without-objects included actions like crawling, flying, running, hopping, praying, descending, and dancing. This category also corresponded to the transitivity of the English verb that the gesture most closely represented.

[2]Boundary gestures behaved more like conventional gestures than iconic gestures in that they had canonical forms and were not subject to the same degree of flexibility as iconic gestures. Boundary gestures have a degree of iconicity in that they indicate size, but they do not have the potential to provide other information about the shape or motion of entities.

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2.4 Reliability

There were three levels of coding conducted on the video, and each had a different procedure for inter-observer reliability. The first coding pass involved transcribing the speech, identifying where gestures occurred, and categorizing the gestures into types (e.g. deictic, iconic, conventional). Transcribers had to reach 90% inter-observer reliability on a shared transcript before they could transcribe on their own. Following basic transcription, handshape was added in a second coding pass using trained gesture coders. Gesture coders had to reach a 90% threshold of reliability on shared transcripts before they could begin coding. The third coding pass classified gestures as referencing actions or entities, and coded whether the action was performed on an object or without an object. Inter-observer reliability for these variables was measured by asking two additional coders to categorize 10% of the iconic gestures in our dataset. Reliability ranged between 83% and 93% for all iconic gesture codes.

2.5 Gesture corpus

To create the video corpus for the analyses presented here, we excluded three types of gestures. (1) We excluded whole body gestures from our analysis because handshape could not be analyzed in these gestures. Whole body gestures occurred rarely, and accounted for less than 5% of all observed gestures. (2) We excluded gestures in which children were holding objects because handshape was influenced by the held object and could not vary freely. (3) We excluded gestures in which the handshape was ambiguous or hard to see and was thus deemed uncodable. Repetitions of the same gesture within an observation session were kept in the dataset. However, there was one session where a child produced many repetitive gestures relating to blowing up a balloon in the same interaction. Over the course of about 20 minutes, the child produced 73 iconic gestures about blowing up the balloon. We excluded many of the exact gesture repetitions from this session, since inclusion of this bout would dramatically skew the data. We kept 19 of the 73 gestures, focusing on those that described different aspects of the event. The next most numerous bouts of gesture in the corpus contained 16 and 17 gestures each.

3. Methods: homesign

3.1 Participant

We coded data from an American homesigning child, called David, who was born with a profound hearing loss (≥90 decibels) into a hearing family. David was being educated using an oral method and thus was not exposed to a conventional sign language (see Goldin-Meadow, 1979; Goldin-Meadow & Mylander, 1984). David was taught to use visual and kinesthetic cues to understand and produce speech, although his proficiency at these tasks was low despite the hearing aid that he wore. At the time of filming, cochlear implants were not available.

3.2 Data collection

David was videotaped at home during 11 two-hour observation sessions over the period from 34- to 62-months of age. During the observation sessions, experimenters brought toys,

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books, and puzzles to elicit communication, and David interacted spontaneously with his family and the experimenters. If the experimenters were uncertain about David's intended meaning, they would ask his parents for help clarifying meaning or context. These interactions were videotaped and were accessible during the coding process.

3.3 Data coding

The analyses we conducted were based on coding described in Goldin-Meadow and Mylander (1984), Goldin-Meadow, Mylander, and Butcher (1995), and Hunsicker and Goldin-Meadow (2013). Coding was a multi-year process involving multiple coders and many coding passes on the video. As with co-speech gesture, homesign gestures were defined as communicative hand movements directed at other individuals that did not involve ritualized acts or the functional manipulation of objects. Coders classified gestures according to type: *deictic*, *conventional*, *iconic*. David's iconic gestures were then coded for (i) handshape, (ii) referent (entity vs. action), and (iii) whether action gestures transformed objects.

3.3.1 Handshape—Handshape was coded with the same three categories used to code co-speech gesture – *hand-as-hand, hand-as-object*, *hand-as-neutral*. For further explanation of handshape coding in homesign, see Goldin-Meadow and Mylander (1984) and Hunsicker and Goldin-Meadow (2013).

3.3.2 Referent—Gestures were coded as referring to entities (akin to nouns) or actions (akin to verbs). This distinction was based on communicative context rather than gesture form. For example, a gesture based on an action form (e.g. moving fists as though to beat a drum) could be used either to refer to act of beating or to the drum itself (see Goldin-Meadow et al., 1994). Since David's gestures were produced without accompanying speech, this coding decision was made on the basis of gesture alone and thus differed from the referent coding for the co-speech gesture corpus in which the speech that accompanied a gesture could be used to disambiguate the referent of the gesture.

3.3.3 Actions-on-objects and actions-without-objects—We coded whether the action depicted in a gesture affected an object (transitive) or not (intransitive). This distinction does not perfectly align with the linguistic categorization of transitivity of spoken verbs, but it is conceptually similar and largely overlapping (Goldin-Meadow et al., 1994).

3.4 Reliability

Reliability was calculated by having two coders independently transcribe a subset of the videotapes. Agreement between coders was above 90% for defining boundaries of gestures, assigning meaning to gestures, and categorizing gestures as referencing entities or actions. Reliability for handshape coding ranged from 85%–95% agreement (see Goldin-Meadow & Mylander, 1984, and Goldin-Meadow et al., 1994. for additional details about reliability).

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3.5 Gesture corpus

As in our co-speech gesture analyses, gestures made with the whole body were excluded from the corpus, as were gestures in which David was holding an object in his hands (restricting his handshape), and gestures in which the handshape was uncodable.

4. Results

Our final dataset consisted of 807 co-speech gestures produced by 52 children during a total of 512 90-minute observation sessions over a period of 3 years, and 1685 homesign gestures produced by a single child during 11 120-minute observation sessions over a period of almost 3 years. The differences in gesture quantity are striking, with homesigner producing approximately 100 times more iconic gesture than the hearing children.

4.1 Frequency of iconic gesture

Rates of iconic gesture production differed markedly between the hearing children and the homesigner. Hearing children used approximately one iconic gesture per hour (range 0–23 gestures per hour). The homesigner used approximately 77 iconic gestures per hour (range 5–171). In both cases, the frequency of iconic gesturing increased over time, but the homesigner produced 1–2 orders of magnitude more iconic gestures than the hearing children did.

The hearing children differed as a group from the homesigner, but there was also substantial individual variation in co-gesture rates among the hearing children. Figure 1A shows individual differences in the use of iconic co-speech gesture over time. The average rate of iconic gestures in the hearing children was 1.61 (stdev = 0.48) gestures per 90-minute observation session at 14 months and 26.35 (stdev = 22.2) gestures at 50 months. Some children use iconic gesture very infrequently, whereas others are frequent gesturers. These individual differences become more pronounced over time. Figure 1B compares change over development in use of iconic co-speech gesture to change in use of iconic gesture in homesign. The homesigner was not measured until 34 months, so his early development cannot be compared and his data at 34 months are not cumulative from 14–34 months (as the data from co-speech gesture are). The homesigner was also measured at slightly different ages from the hearing children so to better align the data, we averaged together some of his observation sessions (the graphed data point at 34 months is an average of the observations at 34, 35, and 36 months; the point at 42 months is an average of 41 and 44 months; the point at 46 months is an average of 46 and 47 months).

At 34 months, the homesigner used more iconic gestures than almost all of the hearing children, but his data are easy to depict on the same scale. However, the homesigner’s use of iconic gesture quickly eclipsed the hearing children’s use. By the time the children were just over 4-years-old, the homesigner had produced around 30 times as many iconic gestures as the average hearing child. Additionally, the homesigner’s cumulative gesture growth was continuous – there were never any observation sessions without iconic gesture (in contrast, hearing children were sometimes observed for a 90-minute session without producing a single iconic gesture). There were several sessions in which the homesigner’s iconic gesture

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production was lower than the previous session (for example, he produced fewer gestures at the 44 month observation session than he did at the 41 month session), but the cumulative number of gestures over time increased steadily.[3]

4.2 Handshape form over time

Table 1 presents examples of handshapes that the hearing children and the homesigner used to reference objects and actions. To assess whether the iconic resources of gestural handshape develop in different ways for the two types of communicators, we next compared the relative frequency of different handshapes in co-speech gesture (Figure 2A) and homesign (Figure 2B) over time. For this comparison, we looked at total handshape use, ignoring the meanings of the gestures. Although the numbers of gestures differed dramatically between co-speech gesture and homesign (note the differences in the y-axis scale in Figures 2A and 2B), the overall pattern of handshape use was characterized by several similarities. First, in both groups, all three handshape types (hand-as-hand, hand-as-object, hand-as-neutral) were present from the first observation session. This finding implies that one type of gesture was not initially easier for the children to produce than any other type. Second, the relative overall frequencies of the three handshape types were similar for both groups: hand-as-hand was the most frequently used form; hand-as-object was the rarest and showed the least amount of growth; hand-as-neutral was intermediate in both overall frequency and growth.

Adding together the average gestures per child from all 10 observation sessions, we find that the average hearing child used 9.5 hand-as-hand gestures, 4.2 hand-as-object gestures, and 6.6 hand-as-neutral gestures. The relative frequencies for the three handshape types were approximately 10:4:7. The homesigner, for his part, used 906 hand-as-hand gestures, 300 hand-as-object gestures, and 479 hand-as-neutral gestures. The relative frequencies were similar, approximately 9:3:5. The biggest difference between the homesign and co-speech gesture was the growth in hand-as-neutral handshapes in co-speech gesture. By 50 months of age, in co-speech gesture, hand-as-neutral handshapes are used as frequently as hand-as-hand handshapes, whereas, in homesign, hand-as-hand continued to dominate at 62 months of age (the latest observation session). Overall, the patterns of emergence in gesture handshape were similar in co-speech gesture and homesign, suggesting that the process by which children begin to produce iconic mappings between hand and world is driven by general cognitive processes and is not dramatically altered by whether a child is learning a spoken language or creating a manual language.

4.3 Handshape when referencing actions vs. entities

We next explored the relation between gesture form and gesture meaning by examining handshape use for gestures that referenced entities (noun-like) and gestures that referenced actions (verb-like). We compared the patterns of use between co-speech gesture (Figure 3A) and homesign (Figure 3B).

[3]The length of each of the homesign sessions was intended to be 2 hours but ranged from 1.5–2 hours: 34 months: 2:04; 35 months: 1:34; 36 months: 1:32; 39 months: 1:30; 41 months: 2:07; 44 months: 1:51; 46 months: 1:30; 47 months: 2:03; 54 months: 1:35; 58 months: 1:30; 62 months: 1:58.

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In both co-speech gesture and homesign, iconic gestures were used more often to reference actions than entities, another broad similarity between the iconic properties of co-speech gesture and homesign. The bias towards using iconic gesture to depict actions was greatest, however, in co-speech gesture. The average hearing child produced 3 times as many action gestures as entity gestures over the whole study period (the mean was 14.9 action gestures, 4.8 entity gestures). In homesign, by contrast, action gestures were only 1.6 times more common than entity gestures (1002 action gestures, 613 entity gestures). For co-speech gesture, this action bias persisted through 50 months. In homesign, the action bias was strong before 41 months, but weakened after that age (see Goldin-Meadow et al., 1999).

Focusing on distribution of handshape types for actions versus entities, Figure 3A shows that in co-speech gesture, all three handshape types were used to reference actions. Nonetheless, hand-as-hand was the preferred form for action, particularly early in development. Hearing children used all three handshape types to reference entities, but there was no particular preference for any one handshape type over another.

Figure 3B displays comparable data for the homesigner. After 41 months, the homesigner used all three handshape types to reference actions and entities, with no particular preference for any one form over another, and thus resembled the co-speech gesturers. However, before 41 months, although the numbers are small, hand-as-object was used exclusively to reference entities (e.g. HAT, KNIFE) and not actions. Conversely, hand-as-hand and hand-as-neutral were used exclusively for actions (e.g. TWIST, TAKE OFF) and not entities. Thus, as mentioned earlier, handshape served as a linguistic marker for entities (nouns) vs. actions (verbs) in the homesigner's system until age 41 months when he developed other devices to mark the distinction (Hunsicker & Goldin-Meadow, 2013).

4.4 Handshape use when referencing actions-on-objects and actions-without-objects

Finally, we asked whether handshape differed when referencing actions performed on objects (transitive) vs. actions performed without objects (intransitive) in children's co-speech gestures (Figure 4A) and homesign (Figure 4B). Here again, we see broad similarities between co-speech gesture and homesign. Hand-as-hand was the preferred form for actions-on-objects (e.g. TWIST, PUSH) but not for actions-without-objects (e.g. FALL, GO) for both co-speech gesture and homesign. Hand-as-neutral showed the opposite pattern for both groups of children, and was used infrequently for actions on objects, but was common for actions without objects. Hand-as-object was used relatively infrequently for both types of actions in both groups.

The patterns of handshape use for depicting actions-on-objects and actions-without-objects in co-speech gesture and homesign suggest a strong role for the affordances of different kinds of actions in guiding children's handshapes. Actions-on-objects (akin to transitive verbs) involve an agent acting on another object, unlike actions-without-objects (akin to intransitive verbs), which involve an entity moving or changing on its own. The dominant use of hand-as-hand handshapes for actions-on-objects suggests a bias for an iconic mapping between handshape and the real-world hand that manipulates an object. The tendency towards this iconic mapping may underlie the finding that from 58 months onward, this homesigner uses hand-as-hand handshape as a grammatical marker of causation (Rissman &

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Goldin-Meadow, in press). In other words, iconic tendencies in this domain may become generalized and developed as a grammatical rule in homesign, where gesture is the primary mode of communication.

5. Discussion

Gesture plays a qualitatively different role in the communication systems of deaf homesigners (where it is the primary communicative modality) and hearing children (where it is produced along with speech, their primary mode of communication). Iconic gesture has rich communicative potential, particularly the ability to illustrate features of absent objects and events. It is used by both homesigners and hearing children, but at dramatically different rates: the homesigner used around 30 times as many iconic gestures as the average hearing child.

Despite this great difference in frequency in the two groups, the groups use gestural iconicity in similar ways (at least in terms of handshape). In both homesign and co-speech gesture, all three types of handshape (hand-as-hand, hand-as-object, hand-as-neutral) were present from the start of the longitudinal observations. And in both homesign and co-speech gesture, hand-as-hand was the most frequently used handshape, particularly when referencing actions.

Handshapes were also influenced in common ways by features of the events they depict. In both homesign and co-speech gesture, hand-as-hand was most frequently used for actions-on-objects (transitive), whereas hand-as-neutral was most frequently used for actions-without-objects (intransitive). Actions that involve acting *on* or *towards* an object may be most effectively depicted using gestures that highlight the agency of the action – that is, by showing a hand performing an action. Rissman and Goldin-Meadow (in press) argue, in fact, that the homesigner we have described (David) comes to use the hand-as-hand handshape as a linguistic marker of causation. Actions performed without objects, particularly those conveyed by verbs of motion, may be most easily captured using gesture forms that highlight the manner or path of movement – that is, by using a neutral handshape. The patterns of handshape use for these kinds of actions develop in largely similar ways in co-speech gesture and homesign and are likely to be driven by the affordances of the actions they depict.

The similarities we observe suggest that children's developing ability to form iconic mappings between gesture and meaning builds off of common cognitive processes whether gesture is produced along with speech or bears the primary burden of communication. The ability to iconically map handshape to referents in the world emerges in similar ways in homesign and co-speech gesture, although the homesigner eventually incorporates his iconic representations of actions and entities into a linguistic system with morphophonological and morphosyntactic structure. The building blocks of homesign thus appear to be constructed using skills that promote the iconic mapping of hand to world, skills that are found in all children regardless of the language they are learning or creating.

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Once these building blocks emerge, iconic gesture is neither static nor monolithic. It is an adaptive system, adjusting in concert with other semiotic resources to meet the changing communicative needs of children as their developing linguistic systems (be they spoken or signed) become more structured and complex. Iconic gesture varies flexibly based on the type of referent (entities vs. actions). It adapts to the referent's affordances (whether or not the action is performed on an object). And features of iconic gesture can be recruited to solve linguistic problems (like distinguishing nouns from verbs) if and when they arise. For example, when gesture is the main communicative modality – as it is in homesign – handshape may be recruited to serve a particular linguistic role in the absence of other linguistic markers that could do the same work (e.g. handshape marking nouns vs. verbs before 41 months, Hunsicker & Goldin-Meadow, 2013). However, handshape does not seem to be a stable linguistic marker; once children develop other means of performing that linguistic work, handshape becomes a free agent again until it is recruited for another purpose (e.g. marking causality, Rissman & Goldin-Meadow, in press).

The recruitment of handshape as a linguistic marker is observed only in homesign. But it may nonetheless be part of a shared ability to make use of the semiotic tools at hand to accomplish the desired communicative goals. We do not see handshape used to mark linguistic categories in co-speech gesture, perhaps because hearing children experience less pressure to mark the noun/verb distinction in gesture as they already have spoken language markers for these categories. It is possible that hearing children vary their handshape use in ways similar to homesigners *before* they develop noun and verb categories in speech, but the children in our sample produced too few iconic gestures for us to address this question using data from spontaneous conversation. Thus the *potential* to use handshape as an opportunistic linguistic marker may be present in all children, but only recruited when other sources of grammatical marking are not present. Recent experiments provide further evidence for this potential. When spoken forms of grammatical marking are removed experimentally (in particular, when hearing people are asked to communicate using only gesture), ways of distinguishing actions from entities emerge in the manual modality, although they do not follow the clear handshape distinction seen in David's early homesigning (Ortega & Özyürek, in press).

The ability to use handshape in different ways to reference the world iconically appears to emerge in similar ways in all children at first whether or not gesture is the child's primary communicative modality. However, the propensity to use handshape in grammatical ways may emerge only when the manual modality is dominant. This paper represents an important first step in aligning and comparing the development of gestural iconicity in children who are learning a spoken language versus a child who is creating a manual language. Studies involving more children and more frequent sampling are needed to fully explore the relations between linguistic structure, cognitive development, and children's ability to use manual iconicity as a semiotic tool to reference the world around them.

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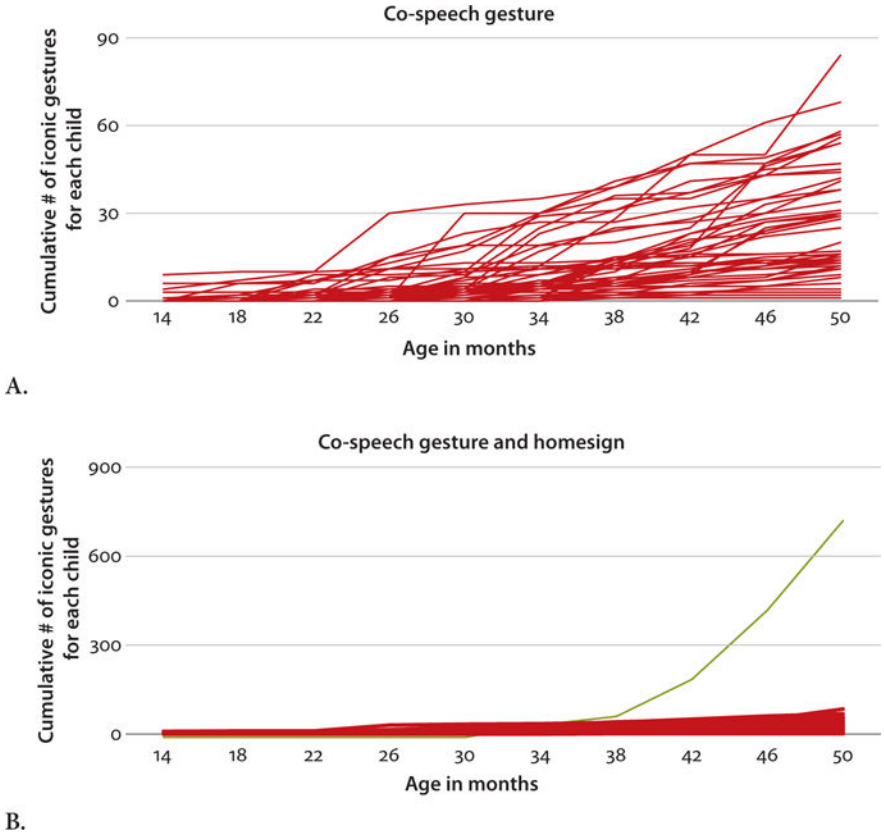

Figure 1.

Individual use of iconic gesture in **co-speech gesture** (A) and **homesign** (B) over time. The y-axis shows the number of gestures each child produced at each observation session. Each line represents a single child's gesturing. The dotted line represents the gesturing of the homesigner. The depiction of gesture use is cumulative so that each time point contains the number of gestures observed up until that point plus any gestures observed at that observation session. The homesigner was not measured until 34 months, so his data are not represented at earlier ages. Since the homesigner was observed at 54 months but not at 50 months, we use his data from 54 months as the graphed data point at 50 months. The homesigner's data from 58 and 62 months are not represented.Note also that the y-axes differ. The homesigner y-axis (B) is 100 times larger than the co-speech gesture (A).

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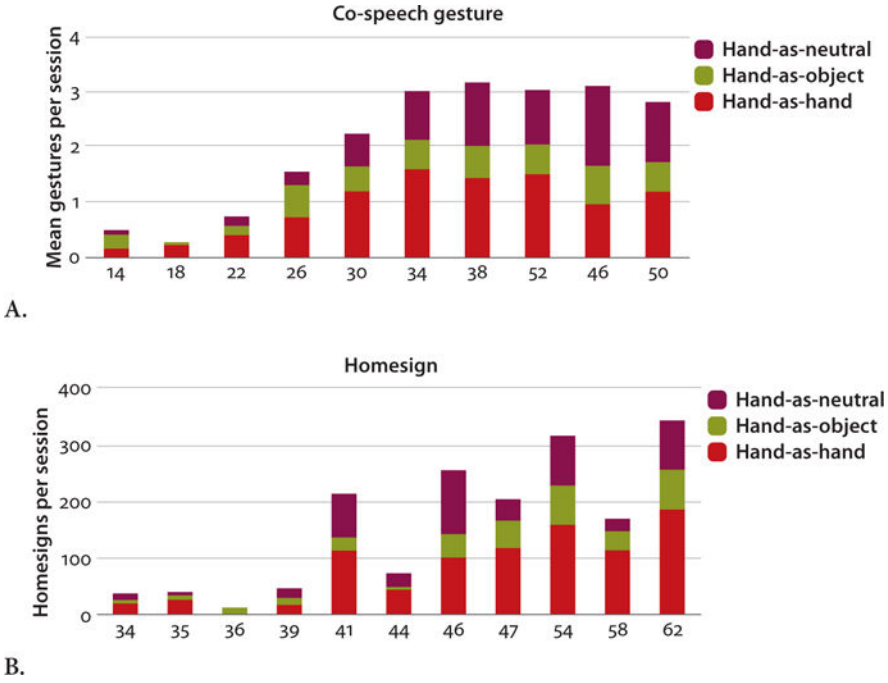

Figure 2.

Iconic handshape use in **co-speech gesture** (A) and **homesign** (B) over time. The y-axis shows the number of gestures each child produced at each observation session. For the co-speech gesture data (A), the number of gestures was averaged across the 52 children. The homesign data (B) are from a single child. The x-axis depicts age in months at each observation session. Note that the observation sessions were conducted at different ages and intervals for the hearing children and the homesigner. Note also that the y-axes differ dramatically. The homesigner y-axis (B) is 100 times larger than the co-speech gesture (A).

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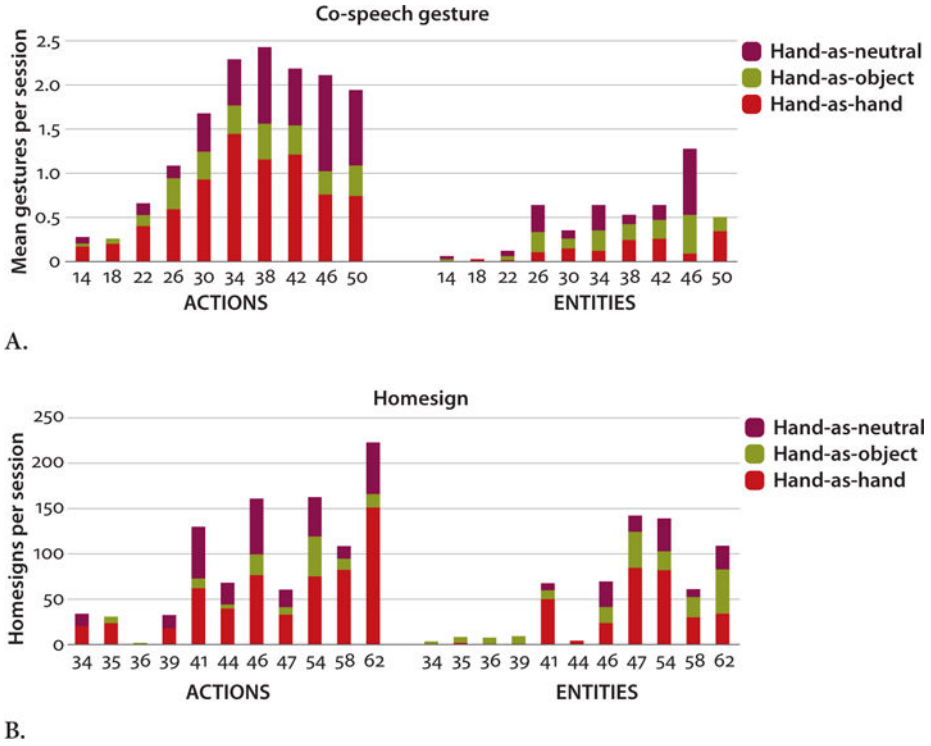

Figure 3.

Use of handshape referencing actions (left) and entities (right) in **co-speech gesture** (A) and **homesign** (B) over time. In A, the number of gestures is averaged across all 52 children. In B, all data are from a single homesigning child. The x-axis depicts age in months at each observation session. Note that both the x-axis and y-axis differ substantially in the co-speech gesture (A) and homesigner (B) graphs.

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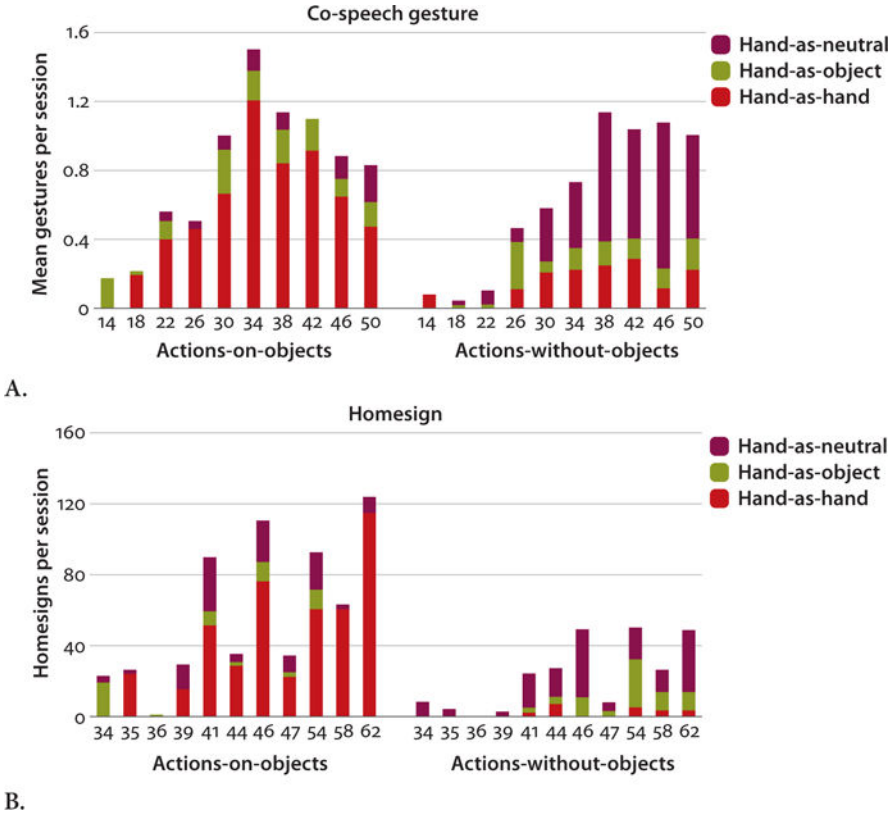

Figure 4.

Use of handshape in gestures referencing actions-on-objects (left) and actions-without-objects (right) for **co-speech gesture** (A) and **homesign** (B). Number of gestures is averaged across all 52 children. In A, the number of gestures is averaged across all 52 children. In B, all data are from a single homesigning child. The x-axis depicts age in months at each observation session. As in the other figures, note that both the x-axis and y-axis differ substantially in the co-speech gesture (A) and the homesign (B) graphs.

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Table 1

Examples of handshapes used to reference objects and actions in co-speech gesture and homesign. Age of child is given in the form (year;months) in each cell.

	Referencing Object (noun-like)	Referencing Action (verb-like)
Co-Speech Gesture	**Hand-as-hand** (4;2) Childpinches fingers together at sides as if grabbing ends of imaginary towel behind her. Pulls hands around and across body as if wrapping towel around herself while saying “then it can be a towel.” Gesture references *a towel*.	**Hand-as-hand**(1;10) Child raises hand above head with palm facing outward as if throwing an object. Gesture references *throwing*.
	Hand-as-object (4;6) Child holds two fingers pointed downward like legs and places them on an imaginary cake while saying “and I want a princess on my cake.” Gesture references a *princess decoration*.	**Hand-as-object** (3;2) Child taps closed fist against head to represent a ball hitting a rabbit on the head in a story. Gesture references *hitting*.
	Hand-as-neutral (3;2) Child uses index finger to draw several radiating lines in the air while saying “I want it sun points.” Gesture references *sun rays*.	**Hand-as-neutral** (4;6) Child moves relaxed hand in arc in front of body while saying “had to go outside and he jumped over the big pool.” Gesture references *jumping*.
Homesign	**Hand-as-hand (3;5)** Child holds fingers in a horizontally-oriented C-shape near chin. Gesture references a *banana*.	**Hand-as-hand** (3;11) Child holds fists in front of his chest, moving them up and down. Gesture references *beating a drum*.
	Hand-as-object (2;10) Child places left hand on head. Hand is flat and palm is down. Hand pats head several times. Gesture references a hat.	**Hand-as-object** (4;6) Child swings hand up and down in front of body. Gesture references *paddling*.
	Hand-as-neutral (3;5) Child moves flat hand in a circle, tracing the shape of a circular train track. Gesture references *a train track*.	**Hand-as-neutral** (3;11) Child extends index finger to request turning around a bag of toys; index finger traces the path of the bag. Gesture references *turning*.
Co-Speech Gesture	**Hand-as-hand** (4;2) Childpinches fingers together at sides as if grabbing ends of imaginary towel behind her. Pulls hands around and across body as if wrapping towel around herself while saying “then it can be a towel.” Gesture references *a towel*.	**Hand-as-hand**(1;10) Child raises hand above head with palm facing outward as if throwing an object. Gesture references *throwing*.
	Hand-as-object (4;6) Child holds two fingers pointed downward like legs and places them on an imaginary cake while saying “and I want a princess on my cake.” Gesture references a *princess decoration*.	**Hand-as-object** (3;2) Child taps closed fist against head to represent a ball hitting a rabbit on the head in a story. Gesture references *hitting*.
	Hand-as-neutral (3;2) Child uses index finger to draw several radiating lines in the air while saying “I want it sun points.” Gesture references *sun rays*.	**Hand-as-neutral** (4;6) Child moves relaxed hand in arc in front of body while saying “had to go outside and he jumped over the big pool.” Gesture references *jumping*.
Homesign	**Hand-as-hand (3;5)** Child holds fingers in a horizontally-oriented C-shape near chin. Gesture references a *banana*.	**Hand-as-hand** (3;11) Child holds fists in front of his chest, moving them up and down. Gesture references *beating a drum*.
	Hand-as-object (2;10) Child places left hand on head. Hand is flat and palm is down. Hand pats head several times. Gesture references a hat.	**Hand-as-object** (4;6) Child swings hand up and down in front of body. Gesture references *paddling*.
	Hand-as-neutral (3;5) Child moves flat hand in a circle, tracing the shape of a circular train track. Gesture references *a train track*.	**Hand-as-neutral** (3;11) Child extends index finger to request turning around a bag of toys; index finger traces the path of the bag. Gesture references *turning*.