

The Development of Causal Structure without a Language Model

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ABSTRACT

Across a diverse range of languages, children proceed through similar stages in their production of causal language: their initial verbs lack internal causal structure, followed by a period during which they produce causative overgeneralizations, indicating knowledge of a productive causative rule. We asked in this study whether a child not exposed to structured linguistic input could create linguistic devices for encoding causation and, if so, whether the emergence of this causal language would follow a trajectory similar to the one observed for children learning language from linguistic input. We show that the child in our study did develop causation-encoding morphology, but only after initially using verbs that lacked internal causal structure. These results suggest that the ability to encode causation linguistically can emerge in the absence of a language model, and that exposure to linguistic input is not the only factor guiding children from one stage to the next in their production of causal language.

Introduction

The languages of the world display a multitude of strategies for expressing causation. Despite this variety, child learners proceed through similar stages when acquiring causal language. Broadly speaking, children's first verbs are felicitously used but show little evidence of internal causal structure. Children demonstrate that they have inferred a productive linguistic rule for expressing causation when they begin to produce causative overgeneralizations, for example, saying *I'm singing him* to mean "I'm making this toy sing" (Bowerman, 1974). Over time, they learn the precise constraints on when to apply these productive rules in the language they are learning (e.g., English allows *I broke the mug* but not *I disappeared the mug*). Acquiring causal language thus involves analyzing linguistic forms in terms of causal structure, as well as mastering the nuances of the particular causative devices in the native language(s).

In this article, we ask whether children who have not been exposed to a conventional language can also develop causal language. We present a longitudinal case study of a child "homesigner," a deaf individual who is unable to learn the spoken language around him and has not been exposed to a signed language. To communicate with the hearing individuals in his world, the child uses gestures, called *homesigns*, that have been shown to have many, although not all, of the properties found in natural language (Feldman, Goldin-Meadow, & Gleitman, 1978; Goldin-Meadow, 2003; Goldin-Meadow & Mylander, 1984). We show that, despite not being exposed to a linguistic model for causal language in his environment, the homesigner develops causal language that has both internal structure and systematicity across a range of verbs. These results demonstrate that structured input is not required for the emergence of causal language, and suggest that typically developing children are likely to approach their ambient language with a bias to infer abstract causative structure from that language.

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Acquisition of causative morphology and syntax

As described by Comrie (1989), languages employ three main strategies for encoding causation: analytic, morphological, and lexical, as in (1–3):

- (1) Analytic (English)
The clown made the girl laugh.
- (2) Morphological (Japanese)
Taroo-ga Hanako-o hasir-ase-ta.
Taroo-NOM Hanako-ACC run-CAUSE-PAST
“Taroo made Hanako run.”
- (3) Lexical (Inuktitut)
puvirtajuuq-ø qaaq-jara
balloon-ABS.SG burst-PAR.1sS.3sO
‘I burst the balloon.’

In the first type, causation is expressed via an additional verb, e.g., English *make*. In the second type, a morpheme attaches to the verb, indicating that the verb is causative, e.g., Japanese *-(s)ase*. In the third, we know the sentence is causative because the verb has both first and third-person inflections, i.e., a person acting on an object (bursting a balloon). Individual languages often display more than one of these strategies, e.g., English has analytic and lexical causatives, but not morphological causatives.

When children acquire causal language, they often go through a period of overgeneralization, inappropriately extending the causative structure in their language; e.g., English (Bowerman, 1974; Braine, Brody, Fisch, Weisberger & Blum, 1990; Hochberg, 1986; Lord, 1979; Maratsos, Gudeman, Gerard-Ngo, & DeHart, 1987), Portuguese (Figueira, 1984), Japanese (Murasugi, Hashimoto, & Fuji, 2007), Taiwan Southern Min (Lin & Tsay, 2008), Hebrew (Berman, 1993), Inuktitut (Allen, 1998) and K’iche’ Maya (Pye, 1994). With respect to the lexical causative strategy, Bowerman (1974) found that her daughters’ early verbal uses were contextually appropriate, but shortly after the children turned 2 years of age, causative errors emerged. For example, one daughter said *she came it over there* to mean “she brought it over there” several months after only using *came* (appropriately) in non-causative contexts. Bowerman hypothesizes that the children had learned a causative derivation rule, whereby non-causative verbs (e.g., *broke* in *the bottle broke*) can be used in a transitive verb frame (*I broke the bottle*) to imply causation, a rule that they then over-applied to verbs like *came*, which do not have this flexibility in English. Similarly, with respect to the morphological causative strategy, Murasugi et al. (2007) present examples of Japanese-speaking children failing to produce a causative morpheme and producing an intransitive form instead in a causative context, as well as examples of children overextending the causative morpheme *-(s)ase*.

A common trend across these studies is that overgeneralizations, which provide convincing evidence for productive knowledge of causal language, do not emerge right away in children’s spontaneous speech. Given this latency, researchers have proposed that children’s early verbs should not be analyzed as causally complex. For example, Bowerman hypothesizes that her children’s early uses of verbs such as *open* and *break* “are essentially ‘unanalyzed’ forms. . .the child is not yet in any sense aware of their internal structure” (1974, p. 154). Similarly, Allen (1998) suggests that “children have not yet discovered causation as a cognitive concept at this stage and thus are not intending to express causation at all” (647). Working within a generative syntactic framework, Murasugi et al. (2007) propose that children initially assume that the $[\pm\textit{cause}]$ feature on little-*v* is phonetically null.

Given robust evidence that pre-linguistic infants make a variety of inferences about causal relations among people and objects (see Saxe & Carey, 2006 for review), we assume that children producing their first verbs do have concepts about causation. However, they may not initially be able to represent these concepts linguistically. That is, children's earliest verbs may not reflect causal *analysis*—the understanding that causative events involve a causal component and a result component, and that causative markers (e.g., the Japanese morpheme—(s)*ase*) encode just the causal component. In order to bridge the gap between conceptual and linguistic knowledge of causation, children may need exposure to causal structures in language. Bowerman, for example, suggests that her children constructed their causative derivation rule via analogy to alternating verbs such as *break* and *open* (i.e., *John broke the glass/the glass broke*). If linguistic input is crucial for this developmental step, it may be that homesigning children do not encode causation in their gestures.

Causal structure in the manual modality

Homesign

Given a variety of cultural and situational factors, deaf children born to hearing parents are sometimes not exposed to a signed language. As noted earlier, such children often use gestures, known as *homesigns*, to communicate with hearing family and friends. Many studies, drawing on data from homesigning children and adults around the world, have shown that homesign displays structural regularities and linguistic categories found in established languages; for example, consistent word order (Goldin-Meadow & Mylander, 1998), word-level morphology (Goldin-Meadow, Mylander, & Butcher, 1995; Goldin-Meadow, Mylander & Franklin, 2007) a noun/verb distinction (Goldin-Meadow, Butcher, Mylander, & Dodge, 1994; Hunsicker & Goldin-Meadow, 2013), proposition-level negation (Franklin, Giannakidou, & Goldin-Meadow, 2011), hierarchically-structured nominal constituents (Hunsicker & Goldin-Meadow, 2012), and motion event categories (Zheng & Goldin-Meadow, 2002).

The gestural systems used by homesigners offer an important type of “natural experiment”—because homesigners are raised in a socially rich environment but are not learning an established language, their gestures suggest biases in how we, as humans, structure our communication. In this article, we investigate whether a child homesigner uses agentive morphology to systematically mark causation. We also measure rates of verbal compounding in this child's gestures, which provide evidence of linguistic analysis of events, including causal event analysis.

Agentive morphology

In signed languages, spatial verbs, or “classifier” predicates, are notable for how the handshape of the verb can represent properties of the participants in the event (Supalla, 1986; chapters in Emmorey, 2003). **Figure 1** demonstrates the contrast between a verb with *handling handshape* vs. a verb with *object handshape*. In panel A, a signer of American Sign Language (ASL) is describing a person putting down a pen, and the form of the signer's hand represents how the person's hand grasps the pen. In panel B, by contrast, the signer's hand represents the shape of the pen itself.

Benedicto and Brentari (2004) argue that, in ASL, the handling morpheme (**Figure 1A**) has the syntactic status of an agentive functional head, which marks a clause as being transitive (see also Kegl, 1990). The association between agency and handling handshape has been observed in many signed languages (Benedicto & Brentari, 2004; Benedicto, Cvejanov, & Quer, 2007; Brentari, DiRenzo, Keane, & Volterra, 2014), as well as in child and adult homesigners (Brentari, Coppola, Jung, & Goldin-Meadow, 2013; Coppola & Brentari, 2014; Goldin-Meadow, Brentari, Coppola, Horton, & Senghas, 2015). For example, Coppola and Brentari (2014) asked a Nicaraguan homesigning boy at ages 7;4–12;8 (yrs;mos) to describe events with an agent (e.g., a person putting down a pen), as well as events without an agent (e.g., a pen rolling off the table). They found that the boy was significantly more likely to use handling handshape in the presence of an agent than in its absence.

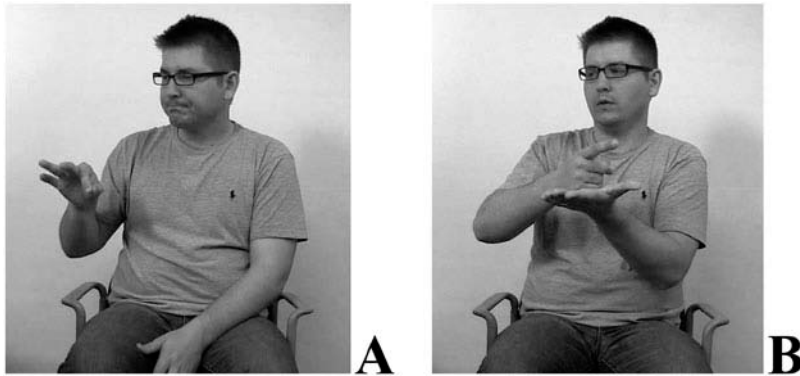


Figure 1. An ASL signer producing a verb with a *handling* handshape to indicate that someone is putting down a pen (A) vs. the same verb with an *object* handshape to indicate a pen falling down (B).

To assess whether our child homesigner encodes causation linguistically, we ask in our study whether he uses handling handshape consistently in causative contexts and, importantly, avoids using this morphological marker in inchoative contexts. Crucially, we focus on verbs for which the presence of handling handshape marks causation; for example, in [Figure 1](#), the handling handshape combined with the predicate MOVE indicates that the man *caused* the pen to move.¹

Verbal compounds

As described above, learning causal language requires being able to analyze an event in terms of a causal component and a result component, and mapping a linguistic form to the causal component. In our study, we measure verbal compounding as a general indicator of the homesigner's ability to analyze events: in a verbal compound, multiple signs convey different aspects of the same event. Verbal compounding has been used as an index of linguistic decomposition in emerging signed languages. Senghas, Kita, and Özyürek (2004), for example, showed videos of motion events involving both manner and path (e.g., a ball rolling down a hill) to signers of Nicaraguan Sign Language (NSL) and to hearing speakers in Nicaragua. They found that the hearing speakers produced gestures that conflated manner and path into a single form (e.g., rotating the hand while moving it downward). In contrast, NSL signers, particularly in the later generations, produced signs that deconflated manner and path (e.g., producing a sign for manner, followed by a separate sign for path). This type of verbal compounding shows signers moving toward a componential system, where smaller pieces of segmented meaning are combined to express more complex ideas (see also Özyürek, Furman, & Goldin-Meadow, 2014).

Producing verbal compounds indicates that the child can map individual components of an event onto separate linguistic forms. This skill is prerequisite to the emergence of causal language: the child must be able to distinguish the means of an event from the result of an event in order to represent the causal link between them. In this study, we measured the homesigner's production of compounds where the first sign expresses a cause and the second sign expresses an effect; for example, HIT—FALL to indicate that hitting a man causes him to fall over. Such compounds have been shown to encode causal relations in Hong Kong Sign Language (Tang & Yang, 2007) and Danish Sign Language (Engberg-Pedersen, 2010). We also measured production of manner/path

¹The need to focus on particular verbs is also evident in studies of English causal language. When verbs like *open* and *break* appear in a transitive syntactic frame, a causal meaning is produced: The sentence *John opened the door* entails that John caused the door to open. This does not mean, however, that English transitive sentences are necessarily causative, cf. *I love cookies*; *I want a bath*. We assume that, in English, causativity is encoded via an interaction of transitivity and verb meaning. Similarly, we suggest that, in David's homesigns, causativity is encoded via an interaction of the handling morpheme (which appears in transitive contexts) and verbs expressing events of change. See Section 2.2.2 for a description of how we selected these verbs.

compounds, such as ROLL—DOWN, which do not encode causation but do indicate the emergence of linguistic event analysis.

To reiterate our research questions, we ask in this study whether causal language can emerge in the absence of a language model, where causal language requires both causal event analysis and systematic use of a particular marker of causation.

Methods

Participant

We observed the spontaneous gestures of an American homesigning boy from the Philadelphia area whom we call David. David was observed for 11 sessions in his home, from age 2;10 to 5;2, with each session lasting 90 minutes. David is profoundly deaf (>90 dB bilateral hearing loss), and his parents had chosen to educate him using an oral method. At the time of our observations, David had not been exposed to a conventional sign language, and his spoken language skills were quite limited, as he was only able to produce a handful of words in isolation. Among the homesigners studied in our lab, we selected David to address our research questions because he was a highly productive gesturer and produced many verbs, and because we have the richest developmental data for David. Our study is thus comparable to the case study, longitudinal investigations of hearing children's causal language discussed in Section 1.1.

Coding

At each session, experimenters engaged with David using a variety of toys and picture books, or observed David interacting with his caregivers and siblings. For the purpose of comparing across sessions, the experimenters brought many of the same toys and books to each session. David's gestures were largely oriented towards describing the here-and-now, which made it easier for us to infer the meanings David intended to communicate.

Gestures and gesture strings

We first identified which of David's hand movements were gestures, that is, had symbolic, semantic content. As described in Feldman et al. (1978) and Goldin-Meadow and Mylander (1984), gestures have to be directed towards an individual and cannot be a manipulation of an object, with the exception of *hold-up* gestures, which function to draw the addressee's attention to the object being held. Ritual acts were not considered gestures, for example, playing patty cake or itsy-bitsy spider.

We identified three main types of gestures: deictics, iconics, and conventional gestures. Deictic gestures serve to index an object in the environment and have the form either of a point or an object hold-up. In iconic gestures, the form of the gesture encodes some physical property of the object or action it represents. For example, David flaps his hands at his side to represent the movements a bird makes as it flies (FLY), or he holds up his index finger and thumb forming a circle to represent a round object (PENNY). Finally, conventional gestures have a fixed association of form and meaning known to the individuals in David's hearing community. Examples include a side-to-side headshake meaning "no" or a head nod meaning "yes."

David often strung several gestures together to make a gesture utterance. The boundaries of these gesture utterances were defined using motoric criteria: relaxation of the hand signals the end of a gesture utterance (see Goldin-Meadow & Mylander, 1984).

Verbs

From the pool of David's iconic gestures, we identified those gestures that functioned contextually as verbs, as opposed to nouns or adjectives. This classification was made on the basis of referential intent. If, for example, David pointed to a picture of a bird with its wings spread as though flying and then produced a flapping-wings gesture, we coded this gesture as the verb FLY. If, by contrast, David

pointed to a picture of a bird with its wings on the handlebars of a bicycle while pedaling with its feet and then produced the same flapping-wings gesture, we coded this gesture as the noun BIRD. Goldin-Meadow et al. (1994) showed that David's nouns and verbs are distinguished in their form; for example, gestures classified as nouns based on context were more likely to be abbreviated than gestures classified as verbs (see also Hunsicker & Goldin-Meadow, 2013). In distinguishing nouns and verbs contextually, we used several heuristics. If David's gesture described an object or a picture of a static object, the gesture was coded as a noun. If his gesture matched an action happening in the real world or an action depicted in a book, the gesture was coded as a verb. Ambiguous gestures were excluded from analysis. In total, David produced 1066 verb gestures across all sessions.

We then coded these verb gestures according to whether they labeled an event of change. Drawing on linguistic studies of the distinction between unergative and unaccusative verbs (see Rappaport-Hovav & Levin, 2010; Sorace, 2000), we identified three types of change verbs: (1) change of location verbs, which involve an object crossing space unidirectionally, e.g., PUT, THROW, GO, and TAKE OFF; (2) change of state verbs, which involve a change in the physical integrity of an object, e.g., BREAK, SMASH, and PULL APART; and (3) change of configuration verbs, which involve an object making a non-repeated rotation on an axis, e.g., OPEN, TURN OVER, and TWIST. Examples of non-change verbs include surface contact verbs such as PUSH, HIT, and RUB, activity verbs such as WAVE, BARK, and SPIN (i.e., a top-spinning repeatedly), and consumption verbs such as EAT and DRINK. To be classified as a change verb, the change needed to be encoded in the gesture's movement. For example, David sometimes wiggled his fingers back and forth to depict walking. If the wiggling motion was produced in place, it was coded as non-change; if the motion also involved a path through space, e.g., walking across space, it was coded as a change verb.

Among the change verbs, we identified two specific subtypes based on context: (1) caused change verbs, where David was describing an event of an external agent causing a change in another participant, e.g., David's sister pulling apart Playdoh; and (2) inchoative verbs, where there was no external agent but the object changing could not initiate its own change, e.g., a tower of blocks falling over.

Finally, we coded the handshape of each verb, using four main categories: *handling* and *object* handshape, as described in Section 1.2.2; *neutral* handshape, where the hand was relaxed and not representing any aspect of the event; and *tracing* handshape, where a pointing index finger traced the path of a motion. Crucially, the handshape of a verb was not used to determine whether the verb was a caused change verb vs. an inchoative verb. Verbs with an ambiguous handshape were excluded from the analysis (13% of verbs excluded; see Table 1).

Verbal compounds

Verbal compounds are sequences of two or more contiguous verb gestures in the same utterance, where each gesture has a distinct form and the verbs represent different aspects of the same event. David represented snow falling, for example, via a fluttering fingers motion, FLUTTER, followed by a downward motion with a flattened palm, GO DOWN. We identified verbal compounds in David's

Table 1. Counts of verb tokens at each session and for each caused-change verb type.

Age	Change type			Total # of verbs (# with unambiguous handshape)
	Location	Configuration	State	
2;10	11	12	0	23 (18)
2;11	16	6	3	25 (17)
3;3	11	5	3	19 (15)
3;5	53	8	2	63 (52)
3;8	12	2	0	14 (12)
3;11	22	5	1	28 (28)
4;6	42	5	2	49 (47)
4;10	28	14	0	42 (34)
5;2	62	20	6	88 (81)

gestures by first isolating utterances in which David produced multiple verbs sequentially. Among these multi-verb utterances, we selected utterances where the gestures produced in sequence depicted different aspects of the same event. We coded three types of compounds. (1) Manner-path compounds, where a gesture depicting the manner of a motion event (e.g., fluttering) is followed or preceded by a gesture for the path of a motion event (e.g., falling). These compounds are parallel to the sequential forms described by Senghas et al. (2004) and Özyürek et al. (2014), and indicate linguistic event analysis. Manner-path compounds are a particularly good example of event analysis because the two components of the event (in this case, FLUTTER and GO DOWN) occur simultaneously in the real world, but are represented sequentially with two consecutive gestures. (2) Handling compounds, where one gesture represents a hand holding or grasping an object, and the other gesture is a change verb, according to the criteria above. For example, in one session, David is asking the experimenter to lift a bag of toys: he produces a static HOLD gesture followed immediately by a LIFT gesture. We included these compounds because they reflect analysis of the event into its parts (here again, the two components of the event occur simultaneously in the world, but are represented sequentially in the gestures) and because the HOLD gesture may itself reflect knowledge of causation. (3) Cause-effect compounds, where one gesture encodes a causal action and the other gesture represents the result. For example, David had a toy turtle that would move forward by twisting a knob. He signed TWIST and then GO to communicate that, after the knob is twisted, the turtle would go forward. These compounds reflect knowledge of causal structure.

Reliability

Reliability was determined by having two independent coders transcribe the videotapes. Agreement between coders was 91% for isolating gestures from the stream of motor behavior, 93% for determining boundaries between signs, and 95% for determining boundaries between sentences. Agreement was 93% for assigning meanings to deictic and iconic gestures, 94% for deciding whether an iconic gesture served a noun or verb, and 95% for coding the handshape of an iconic gesture. Agreement was 96% for distinguishing change verbs from non-change verbs, 93% for distinguishing caused-change verbs from inchoative verbs, and 96% for identifying verbal compounds.

Results

Verbal compounds

Across all sessions, David produced 38 total verbal compounds. [Figure 2](#) shows the number and type of compounds he produced at each session.

Although David produces many verbs in his earliest sessions and even combines verbs into complex sentences containing more than one proposition (e.g., GIVE—GIVE to mean “Mom gives me a cookie and then sister gives me a cookie,” Goldin-Meadow & Mylander, 1998, [Figure 3](#)), he does not produce verbal compounds until age 3;5. By age 3;8, he has produced all three types of compounds, and from age 3;10 and beyond, he produces all three types at each session. His robust production of verbal compounds in spontaneous communication suggests that, by age 3;5, David is able to linguistically decompose events, a necessary step for the development of causal language. In addition, the emergence of handling compounds and cause-effect compounds indicates that David can map the causal component and the result component of an event onto separate linguistic forms.

Agentive morphology

We next asked whether David uses handling handshape consistently in causative contexts. Across all sessions, David produced 304 caused-change verbs with unambiguous handshape. [Table 1](#) shows the number of verbal tokens that David produced at each session, across the three caused-change types

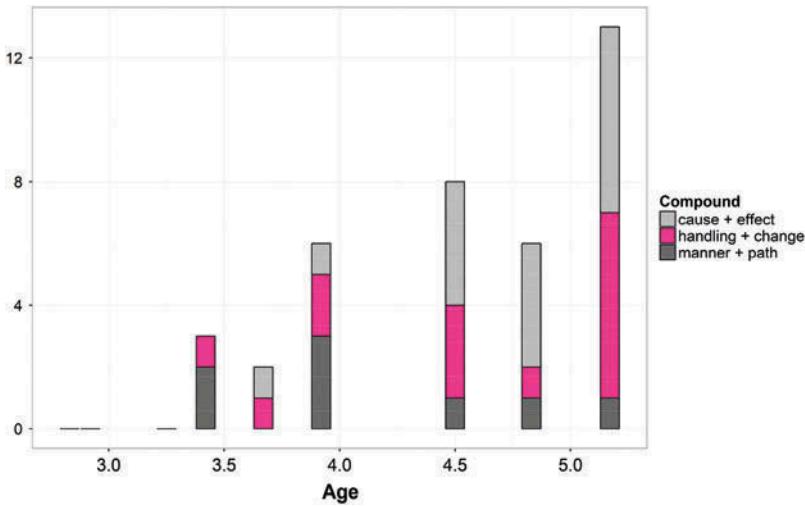


Figure 2. Number and type of verbal compounds produced by David at each session.

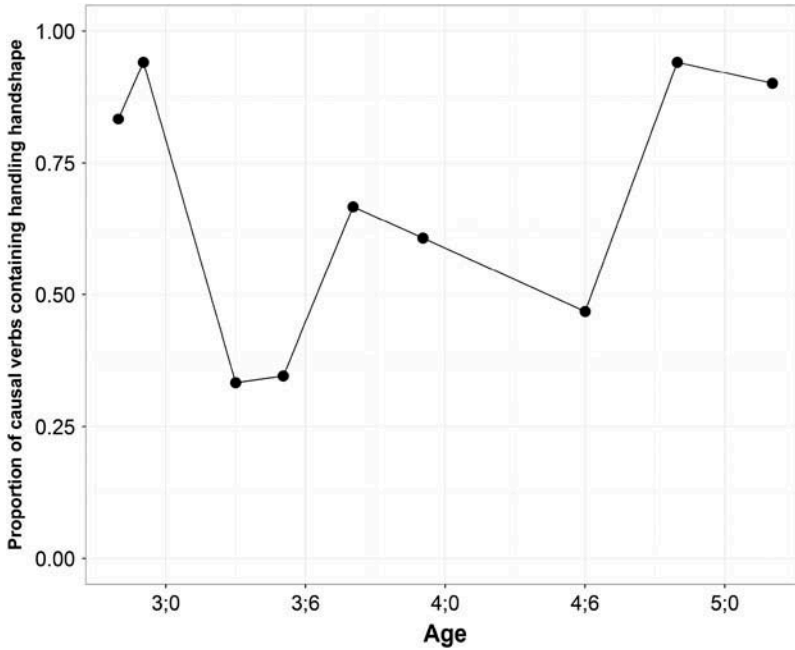


Figure 3. Proportion of caused-change verbs containing handling handshape that David produced at each session.

discussed in Section 2.2.2. As Table 1 shows, change of location verbs dominated David’s verbal lexicon.

Figure 3 shows for each session the proportion of caused-change verbs with unambiguous handshape that contained a handling handshape.

Given the robust association between agency and handling handshape described in Section 1.2.3, we might have expected David’s use of handling handshape to be consistently high, or to show an upward pattern of growth over time. Instead, we observe a distinctive U-shaped curve, where use of handling handshape in causative contexts is initially over 90%, then drops to 33% at ages 3;3–3;5,

and then rebounds to over 90% at ages 4;10 and 5;2. In the middle “trough” period, David is describing many causative events, but is not using handling handshapes to do so. For example, David produces a TURN gesture to ask the experimenter to turn a bag of toys around, but uses a neutral handshape in his representation of the turning.

Crucially, the trough period in [Figure 3](#) begins at 3;3, roughly the same age that David starts producing verbal compounds (3;5). The close timing of these two onsets suggests that they may both be a product of a structural change taking place in David’s linguistic system around this age. These onsets, in turn, are reminiscent of the change observed in hearing children learning a spoken language when they start producing causative overgeneralizations. In hearing children, overgeneralizations are evidence for linguistic causal structure—saying *he falled it* suggests that the child has acquired a general rule for describing a causal event, and has overextended intransitive *fall* to a transitive context. Similarly, during the trough, David is using non-handling forms (which are non-causative) to describe causal events, and he starts to do so at the same time that we have evidence for linguistic decomposition from other parts of his system (verbal compounds). For both children learning language from a linguistic model and for David, who is creating his gesture system without linguistic input, these changes indicate the emergence of internally structured causal language.

[Figure 3](#) shows that David’s use of handling handshape in causative contexts rebounds at age 4;10. We interpret this pattern as indicating that handling handshape, after a significant period of development, is now systematically marking the causative component of an event in David’s gesture system. In other words, at David’s latest sessions, handling handshape for change verbs has a near-obligatory linguistic function similar to the function found in established signed languages; that is, the interaction of handling handshape with the verb expresses causation. This analysis assumes that handling handshapes are not increasing among caused-change verbs at ages 4;10 and 5;2 simply because handling handshapes increase across all verb types. To test this assumption, we display in [Table 2](#) handling vs. non-handling handshapes in caused-change verbs, compared to handling vs. non-handling handshapes in inchoative verbs (i.e., change verbs that do not involve an external agent, e.g., *bear FALL over*).

Although David produces many fewer inchoative verb tokens (which describe non-causative contexts) overall than caused-change tokens, [Table 2](#) shows that almost all of David’s inchoative verbs contain non-handling handshapes. These data thus disconfirm the hypothesis that use of handling handshape is high across all verbs at the latest sessions, and lend weight to the hypothesis that the increase in handling handshapes during the third period is specific to caused-change verbs.

An alternate explanation for the U-shaped pattern seen in [Figure 3](#) is that David uses handling handshape more often for some meanings than for others (e.g., OPEN vs. MOVE), and that the handling-favoring meanings happened to be more prevalent during the earliest period and the latest period (and not during the trough period). To address this possibility, we used English glosses as a rough way of categorizing his verb gestures into meaning types (keeping in mind that David’s lexicon is not equivalent to the lexicon of English). We identified 12 caused-change verb types that each appeared more than five times across the entire study: GRASP, HOLD, MOVE, PULL, PUSH, PUT, ROLL, TAKE, THROW, TRANSFER, TURN, and TWIST. Together, these 12 types accounted

Table 2. Proportion of caused-change vs. inchoative verbs that contain either a handling or non-handling handshape produced during Period 1 (2;10–2;11), Period 2 (3;3–4;6) and Period 3 (4;10–5;2).

Verb type	Period 1		Period 2		Period 3	
	Caused-change	Inchoative	Caused-change	Inchoative	Caused-change	Inchoative
# verb tokens	35	8	154	24	115	13
Verbs with Handling handshape	.89	.00	.45	.04	.91	.08
Verbs with Non-handling handshape	.11	1.00	.55	.96	.09	.92

for 83% of David's caused-change verbs. Of these 12 verb types, 7 were used by David at all three periods in [Figure 3](#), and another 3 were used at both the second and third periods. The remaining 2 verb types were used relatively infrequently and only during the second period: ROLL (11) and GRASP (7). Thus the types of meanings David conveyed were fairly stable across the study period, suggesting that the changes in [Figure 3](#) are not an accident of particular meanings being favored by David at particular sessions. The fact that the last session involves considerably more verb tokens than any of the previous sessions (see [Table 1](#)) also means that the high proportion of handling handshape at this session is less likely to be a product of chance.

Discussion and conclusion

In this article, we investigated whether a homesigning child not exposed to structured linguistic input would nonetheless produce causal language. We found a striking U-shaped curve, where use of handling handshape in causative contexts was initially high (and therefore seemingly similar to patterns found in established sign languages), followed by a dip during which David used many non-handling handshapes to describe causal events, followed finally by a rebound in use of handling handshapes to the initial level. Crucially, the dip in the curve occurred close to the age at which David started producing verbal compounds, which are evidence for linguistic event decomposition. Interpreting these findings in tandem, we suggest that David develops causal language that has both internal structure (the handling handshape marks CAUSE) and systematicity (the handling handshape nearly obligatorily marks the causative component of an event), but only after a significant period of development.

At David's earliest sessions, where use of handling handshape is high, we suggest that he is using the handling handshape mimetically; that is, he is pantomiming how actions, such as twisting the lid off a jar, are performed, but the gesture has no internal morphological structure. This period is parallel to the initial stage discussed by Bowerman (1974) when children's causal verbs are correct on the surface, but unanalyzed. Although David never used handling handshape for inchoative verbs during this period (see [Table 2](#)), this pattern does not mean that he was using handshape contrastively. Rather, we suggest that non-handling handshapes were also used as mimetically as possible for inchoative verbs. As discussed in Section 1.1, we assume that David has access to concepts about causation much earlier than this first period, where David is age 2;10–2;11.

David's verbs gain internal causal structure during the reorganizational period that begins around age 3;3, the moment when he begins to produce verbal compounds and when his use of handling handshape in causative contexts drops dramatically. This reorganization cannot be attributed to input from a conventional language model as it often is in children learning language from a language model, as David had no model. Previous research on David shows that his homesign system undergoes a variety of changes around this age (see Goldin-Meadow, 2003, chapter 12). (1) He imposes a morphological organization on his lexical stems, thus transforming his lexicon from an unorganized collection of gestures into a system of contrasting morphemes that work within a grammatical system (Goldin-Meadow et al., 1995). (2) He begins to use grammatical devices to mark noun vs. verb vs. adjective (Goldin-Meadow et al., 1994), and abandons using handshape to distinguish nouns from verbs (before this point, he used object handshapes exclusively for nouns, and handling, conventional or trace handshapes for verbs, Hunsicker & Goldin-Meadow, 2013). (3) He begins to use deictic pointing gestures and the placement of iconic gestures to refer to objects that are not in the here-and-now, thus using his gestures in an increasingly symbolic fashion (Butcher, Mylander, & Goldin-Meadow, 1991). We add to this developmental list of resilient properties appearing around age 3;5 the ability to map subcomponents of events onto linguistic forms.

These changes may be the result of maturation, where particular resilient organizational properties only come online at a certain age. Another possibility is that the changes arise as a function of the growing complexity underlying the messages David is trying to communicate. David is

developing cognitively and socially, which may result in a greater variety and complexity of concepts to be communicated. A linguistic system not organized by grammatical devices may simply be too unwieldy for this more complex communication, leading to the emergence of these resilient properties of language.

Around age 3;3–3;5, David had developed a morphological system (see Goldin-Meadow, 2003; Goldin-Meadow et al., 1995, 2007), and was able to map linguistic forms to event subcomponents. However, at that point in his developing system, David had not yet created a systematic mapping between the handling morpheme and the concept CAUSE. Why did it take him an additional year and a half after the first signs of event analysis to develop this systematic relationship? During the period between 3;5 and 4;10 (the “trough” phase in Figure 3), David used non-handling verbs for the majority of causative events (e.g., a rotating pointing neutral finger, as opposed to a handling handshape, to communicate “turn that bag around”). Such non-handling forms emphasize the change undergone by the patient in a causative context—the result sub-event. The result may have been more salient for David than the agentive cause. Homesigners across cultures are more likely to mention the patient of a transitive event than the agent (Goldin-Meadow, 2003; Goldin-Meadow & Mylander, 1998), suggesting that children may be biased to focus on affected rather than affecting participants in an event. Further support for this hypothesis comes from cross-linguistic evidence. Slobin (1985, p. 7) notes that children’s earliest use of grammatical markers reflects result-oriented categories; for example, past tense markers appear first on result-oriented verbs such as *fall* and only later are extended to verbs that are not result-focused. If, as Slobin argues, an object’s affectedness is a particularly salient conceptual perspective for young children, it would not be at all surprising that David uses so many non-handling forms in causative contexts, once his verbs gain internal causal structure.

By 4;10, David was linguistically encoding not only the result of a causation event, but also systematically encoding its cause; expressing causation thus appears to be a resilient property of language. Developing and systematizing this causative morpheme was a seemingly time-consuming process for David. The relatively slow pace of this change perhaps reflects the fact that causation is expressed in different ways across languages, and children must be open to receiving the particular causative structures in the language(s) they are learning. However, we do not know whether coming to use handling handshape to express causation was more, or less, time-consuming for David than it is for a deaf child learning sign language from his deaf parents. Comparing David’s developmental course to deaf children exposed to ASL would give us some idea of how difficult it is to *construct* a mapping between the handling morpheme and the concept CAUSE, as opposed to learning the mapping from a language model.

What can David’s development of causal language tell us about how typically developing children acquire causative structures? The fact that David developed causation-encoding morphology without the benefit of a language model suggests that all children approach language learning with the expectation that linguistic forms can encode event subcomponents in general and CAUSE in particular. Our data thus suggest that children who are learning English need not experience alternating causative/inchoative sentences, such as *Freddie broke the mug/the mug broke*, to infer internal causal structure, as suggested by Bowerman (1974). Rather than such contrasts leading children to analyze events into subcomponents, the direction of learning may go the other way—having an expectation that linguistic forms encode subcomponents may help children take advantage of contrasts such as *Freddie broke the mug/the mug broke* to learn the fact that transitive syntax encodes causation in English.

Our data thus suggest that children come to language-learning expecting linguistic forms to encode subcomponents of events. Nonetheless, children who are learning language from a model must learn the particular forms that their language offers to encode subcomponents like CAUSE. This learning hurdle could be the reason that children exposed to linguistic input begin describing causal events using unanalyzed verbs, and only later analyze these verbs into subcomponents. David displays the same delay—his first descriptions of a causal event are unanalyzed mimetic gestures,

and it is only later in development that he analyzes these gestures into components. This parallel suggests that certain developmental milestones (e.g., having a verb category; understanding that events have subcomponents that can be linguistically marked) must be in place before a child can do the analytic work that results in a systematic causative structure, whether or not the child is exposed to a language model.

One drawback of our study is that we have only a limited set of analytical tools to assess whether handling handshape is functioning as a productive morpheme at David's latest sessions. In ASL, an established sign language, multiple linguistic diagnostics can be used (along with the observation that use of handling handshape is high in causative contexts) to confirm the agentive status of the handling handshape in classifier constructions (see Benedicto & Brentari, 2004). Given that David is creating his own communication system, such diagnostics are not available. We therefore cannot definitively rule out the possibility that handling handshape is high at the later sessions as a result of random factors not reflective of linguistic structure. Nonetheless, the changes across sessions do not appear to be a product of overall increases in handling handshape, nor a lopsided distribution in the types of meanings expressed at each session.

In conclusion, we have found that a child who does not have access to a usable language model can nevertheless introduce notions of causation into his self-made communication system. Initially, the child conveys causation mimetically, using gestures that resemble the activities he is representing. Over time, however, the child begins to use a form--the handling handshape--to represent CAUSE, but only after he is able to linguistically decompose events; that is, after he begins to produce verbal compounds (Section 3.1), and after he imposes a morphological system onto his gestures (Goldin-Meadow et al., 1995). These changes provide evidence that David has moved from internally unanalyzed verbs to productive knowledge of causal structure, just as overgeneralizations provide evidence for such a change in typically developing children. Children acquiring language *with* a linguistic model thus do not depend on causative language in their input to infer the presence of causal structure.

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