


Forum

Whole-to-part
development in
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Children approach language by learning parts and constructing wholes. But they can also first learn wholes and then discover parts. We demonstrate this understudied yet impactful process in children creating language without input. Whole-to-part learning thus need not be driven by hard-to-segment input and is a bias that children bring to language.

Children break into language by using small units to build bigger ones. We see this part-to-whole process when children combine syllables to form words and words to form sentences. Seminal work from the 1990s [1] suggests that children's use of part-to-whole learning is what makes them such good language learners. But children also make use of a complementary process: one that reverses the direction and goes from wholes to parts. Here, children start by learning under-analyzed wholes (e.g., *Ididit*) and only later discover the parts that the wholes are made of (*I did it*). The presence of whole-to-part learning is predicted by usage-based approaches [2] and is consistent with linguistic theories such as construction grammar [3], which recognize the importance of larger form-meaning mappings in human language. Recent work has provided new evidence for this process in children and has shown that the process can lead to better learning than starting from parts [4] (Box 1).

Does difficult-to-segment linguistic input motivate whole-to-part learning?

Building larger structures from smaller units is a natural combinatorial process, reflecting our affinity for hierarchies. But where does whole-to-part learning come from? One possibility is that it grows out of the unsegmented nature of linguistic input. Speech and sign are continuous, without perceptually clear boundaries between words or signs. As a result, children may, at times, segment units that extend beyond a word. Under this scenario, children begin with wholes because they have difficulty extracting the parts that make up these wholes from the linguistic input they receive. The learning advantage is thus a by-product of initially not being able to detect the parts.

A second possibility is that beginning with wholes – and using them to discover parts and the relations between those parts – is a general cognitive process, at play regardless of how segmented the input is. This process might be driven by a communicative need for units, learned or created, that can express early communicative functions (e.g., expressing physical or social needs describing an entire event). Only later, as communicative needs increase and the meaning space grows, will those units be decomposed to create internal structure. Beginning with wholes, and only later analyzing the wholes into parts, may be a bias that children bring to communication rather than just a reaction to difficult-to-segment input.

The best evidence for the hypothesis that whole-to-part learning is a bias that children bring to language would be if the process were to occur even in the absence of linguistic input. All children are exposed to linguistic input, but there are cases where the input is not usable: deaf children whose hearing loss prevents them from acquiring spoken language (even with hearing devices) and whose

Glossary

Homesign: the system of gestures created by a deaf individual who is not exposed to an established sign language and is living in a hearing/speaking world but cannot learn spoken language.

Morphemes: the smallest meaningful pieces of a word, the units from which words are built.

Morphological system: the system that gives the words in a language their internal structure.

Protolanguage: a postulated intermediary stage in the evolution of language, meant to bridge the gap between primate communication and the fully evolved human languages we have today. There are different views on the nature of this postulated stage. In the synthetic account, protolanguage contained atomic symbols that were combined into larger units only in later stages. In the holistic account, protolanguage contained holistic symbols that were decomposed into productive parts in later stages.

Representational redescription: a developmental mechanism through which learners translate (or redescribe) their knowledge into a format that is more abstract and flexible; a concept introduced by Annette Karmiloff-Smith [1].

hearing parents have not exposed them to sign language. Despite their lack of usable linguistic input, these children communicate, and do so using gestures – called **homesigns** (see Glossary) – which display properties of natural language [5]. Importantly, the gestures hearing parents use as they talk with their homesigners are structured differently from homesign and thus cannot serve as a model for it (see references in [5]). Homesign allows us to ask whether children engage in whole-to-part development even when they acquire language without a language model.

Without linguistic input, children can create gestures composed of parts

There is anecdotal evidence that homesigners break their gestures into parts. For example, a homesigner alternately moves his fists upward as though climbing up a ladder to express the meaning CLIMB+UP, and also breaks up this holistic gesture into two sequential gestures to express the same meaning: CLIMB (two fists alternately grabbing in place), followed by UP (pointing handshape moving up). But examples of this sort do not guarantee that homesigners' gestures are composed

Box 1. Whole-to-part learning

Whole-to-part learning refers to a class of processes whereby learners start with under-analyzed wholes and only later discover the parts those wholes are made of. Whole-to-part learning happens when a child discovers morphemes from an inflected word, or words from an under-analyzed multiword sequence. Although language learning is often described as a move from smaller to larger and more complex units, there is growing evidence for the existence, and importance, of the reverse process: discovering parts from wholes [12]. Children draw on multiword units during early learning. Preverbal infants are sensitive to multiword frequency in their input, indicating they have already extracted this information [4]. Older children are faster and more accurate at producing higher-frequency phrases, showing their reliance on larger units in production [13]. Traces of early acquired units can be detected in adults; they are faster to respond to early-acquired sequences than to later-acquired ones, illustrating their status as early building blocks [4].

Recent work shows that whole-to-part learning has a function. It can help children learn grammatical relations; discovering parts from wholes can create stronger associations between the parts than going from parts to wholes [4]. Whole-to-part learning is particularly useful when children acquire arbitrary grammatical relations that hold across words (e.g., gender agreement [13]). Adults' existing knowledge of words makes them less likely to rely on whole-to-part learning, a factor that explains (some of) their difficulty in learning second languages. However, adults can engage in whole-to-part learning under certain conditions, indicating that this learning process is still available to them. For example, adults show better learning of gender agreement [13], an aspect of language that is usually hard to master in a second language, when they are forced to learn from larger units by experimentally manipulating their input to be more 'chunked'. A central remaining question is whether certain linguistic constructions lend themselves to whole-to-part learning, and others to part-to-whole learning, and if so, what characterizes the two sets of constructions.

of productive parts. To make this point, we need to uncover a **morphological system** that accounts for the child's gestures.

To pursue this question, one observation session was selected for each of eight homesigners (four US, four Chinese) [6]. Handshape and motion forms were identified in that session, along with the meanings each child conveyed with their forms. These form/meaning pairings (**morphemes**) for handshapes (e.g., 'FIST' form/'grasp object <1 inch in diameter' meaning) and for motions (e.g., 'REVOLVE' form/'twist' meaning) for each of the eight children were then used to code that child's remaining sessions. The morphemes discovered in one session accounted for almost all the gestures in the remaining sessions. Importantly, the homesigners' morphemes could not be traced to the spontaneous gestures their hearing mothers produced but were instead shaped by the early gestures each child created [7].

Without linguistic input, children can create productive parts from holistic gestures

Homesigners' gestures can be characterized by handshape and motion parts. But

do homesigners begin by creating gesture wholes and only later divide them into parts? If so, their first gestures should be unanalyzed labels for specific events (e.g., FIST/REVOLVE used only for twisting a key). Only later should they relate gestures to one another and organize them around whatever regularities exist in their gestures. FIST would then be used not only for keys but also for drumsticks and toothbrushes, and REVOLVE not only for twisting but also for screwing and rotating.

Figure 1 (left) presents data from one US homesigner consistent with this whole-to-part path. Initially, he uses his gestures for specific events; a very small proportion of his gesture types are thus used for a variety of objects/actions. But the proportion doubles at 39 months and is maintained thereafter [7]. Two other US homesigners show this pattern; the fourth used gestures for a variety of exemplars from his first observation session. There were not enough developmental data to address this question in the Chinese homesigners.

Additional evidence that the US homesigner in Figure 1 began to partition his gestures at

39 months comes from gestures used to describe an agent causing a change in an object. Initially, he used handle handshapes with caused-change motions (e.g., the FIST handshape represents a hand causing the REVOLVE motion). At 39 months, when he began to construct a morphological system, he stopped using handle handshapes with caused-change motions and replaced them with neutral handshapes (e.g., POINT/REVOLVE to represent someone twisting a key). Over time, he gradually replaced the neutral handshape with handle handshapes, suggesting that handle handshapes were now functioning as a causative marker (Figure 1, right) [8]. This U-shaped curve resembles the path hearing children take as they acquire causative constructions in their spoken languages, moving from a correct but unanalyzed whole, through incorrect forms, and back to a correct but analyzed form, now marked as causative (see references in [8]). These findings confirm that children can engage in whole-to-part learning even when not exposed to unsegmented input.

Whole-to-part learning is not unique to first language-learning

Whole-to-part learning is not unique to first language-learning and occurs over different linguistic timelines. It is found in individuals learning in an iterated paradigm where hearing adults initially use pantomime-like gestures to describe an entire event, and only later analyze these wholes into more structured gesture sequences [9]. Whole-to-part learning is also found in a sign language emerging naturally over generations of learners (Nicaraguan Sign Language, see references in [9]). In evolution, holistic forms have been proposed to characterize **protolanguage** (a postulated intermediary stage in the evolution of language), with the transition to combinatorial human language driven by a process of analyzing those wholes into productive parts [10].

What is the motivation behind whole-to-part learning? There are two parts to this

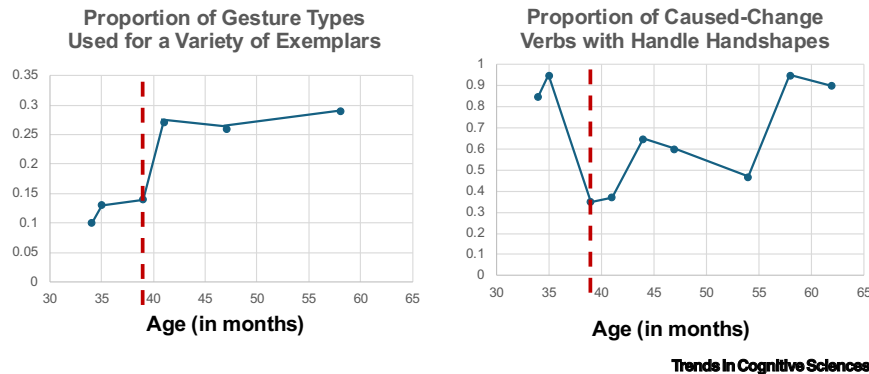


Figure 1. Converging evidence for a morphological system in homesign. Left: the proportion of gesture types (handshape + motion combinations) used for a variety of exemplars over time by a homesigner [7]. Right: the proportion of caused-change gestures the same homesigner produced with handle handshapes; during the trough, the child used neutral handshapes in these gestures (adapted from [8]). The broken vertical line in both graphs indicates the age at which this child began to divide his gestures into morphological parts [6,7].

question. First, what is the advantage of starting with wholes rather than parts? The answer here might involve communicative efficacy: the child's goal of getting a meaning across to their communication partner. From this perspective, holistic units may serve a communicative purpose and reflect pressure to privilege communicative intent over structure, a pressure that operates on children learning language as well as children creating it. Second, why bother to break the whole into parts? Here, the answer may be related to expressivity pressures. Using a handshape/motion combination to refer to only one object/action is limiting. A new handshape/motion combination is needed for every event the child might want to refer to. Creating a set of handshapes that combine freely with a set of motions greatly enlarges the child's communicative potential. In addition, there may be pressure to break wholes into parts that stems from a general cognitive

bias to redescribe knowledge so that it becomes more flexible and less tied to a particular context. This need for **representational redescription** [11] has been used to characterize change over time not only in language but in a variety of cognitive domains.

Concluding remarks

Whatever the motivation for whole-to-part development, our findings offer the first evidence that the process can occur even in the absence of difficult-to-parse linguistic input, indicating that it is a bias children themselves bring to language.

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Declaration of interests

No interests are declared.

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