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When learners surpass their models: The acquisition of American Sign Language from inconsistent input[☆]

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Abstract

The present study examines the impact of highly inconsistent input on language acquisition. The American deaf community provides a unique opportunity to observe children exposed to nonnative language models as their only linguistic input. This research is a detailed case study of one child acquiring his native language in such circumstances. It asks whether this child is capable of organizing a natural language out of input data that are not representative of certain natural language principles. Simon is a deaf child whose deaf parents both learned American Sign Language (ASL) after age 15. Simon's only ASL input is provided by his late-learner parents. The study examines Simon's performance at age 7 on an ASL morphology task, compared with eight children who have native signing parents, and also compared with Simon's own parents. The results show that Simon's production of ASL substantially surpasses that of his parents. Simon's parents, like other late learners of ASL, perform below adult native signing criteria, with many inconsistencies and errors in their use of ASL morphology. In contrast, Simon's performance is much more regular, and in fact on most ASL morphemes is equal to that of children exposed to a native signing model. The results

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thus indicate that Simon is capable of acquiring a regular and orderly morphological rule system for which his input provides only highly inconsistent and noisy data. In addition, the results provide some insight into the mechanisms by which such learning may occur. Although the ASL situation is rare, it reveals clues that may contribute to our understanding of the human capacity for language learning.

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1. Introduction

The acquisition of language by young children is an important example of the nature of human inductive learning. In language acquisition, as in any inductive learning, the learner is presented with a finite sample of items of the system to be learned (in this case, a finite set of sentences); the learner's task is to acquire the rules or patterns of the system from which these items are drawn (in this case, the grammar of the language). The compelling interest of human language acquisition is that the learning succeeds in virtually every normal member of the species, despite the fact that the input data are formally inadequate to explain the success of learning (Chomsky, 1965, 1981; Gold, 1967; Wexler & Culicover, 1980). This outcome has been used to argue that young language learners must bring to the task a set of innate biases or constraints about the types of patterns that they expect natural languages to contain. Theories differ on the nature of such innate constraints, and on issues such as whether these constraints are specific to language or are more general biases shared by other types of pattern learning (Bates & MacWhinney, 1982; Bever, 1970; Chomsky, 1965, 1981, 1995; Keil, 1990; Lerdahl & Jackendoff, 1983; Newport, 1982, 1990; Newport & Aslin, 2004; Slobin, 1973, 1985; Wexler & Culicover, 1980; and many others). Depending on the answers to these questions, a detailed understanding of language acquisition may also shed light on other phenomena of human inductive learning.

There are several types of empirical evidence suggesting that language learners are constrained or biased with regard to the possible forms of grammatical rules or patterns in natural languages. These include findings of similarities (or universals) among unrelated languages of the world (Chomsky, 1965, 1981, 1995); universal patterns or stages in early language acquisition (Slobin, 1973, 1985); and evidence of a critical or sensitive period, early in life, during which language learning must occur to be entirely successful (Curtiss, 1977; Johnson & Newport, 1989; Lenneberg, 1967; Newport, 1990). However, certain types of associated phenomena, which would provide important evidence elaborating this view, have been extremely difficult to study empirically. In particular, given this view of language acquisition, one might predict that children's acquisition would proceed in certain uniform ways even in the absence of relevant supporting linguistic input. For example, if children were exposed to reduced or impoverished input, lacking certain properties of natural linguistic systems, children might nevertheless be capable of imposing these properties on the languages they acquire. This prediction has been difficult to test, since virtually all children are exposed to rich data for their primary language, containing the usual

properties and structures of natural languages. The present study is one of two case studies of a rare child whose input for first language acquisition is not of this usual form. In this paper, we examine the acquisition of a morphological system in ASL for which the child's input provides quite inconsistent and noisy data, to see whether the child is nevertheless capable of imposing the type of regularity and orderliness of morphological rules that is characteristic of natural linguistic systems. In another paper (Singleton & Newport, in preparation), we examine the same child's acquisition of more complex portions of ASL morphology and syntax, where the input is not merely inconsistent, but rather is entirely lacking in its representation of certain architectural properties of rule combination. Both studies thus ask whether the young language learner is indeed capable of organizing a natural language out of input data that are not representative of certain natural language principles. In addition, the studies provide some insight into the mechanisms by which such learning may occur. Before describing our case study, we first review the background issues and the previously available data in more detail.

1.1. Previous studies of impoverished input

Most children are brought up in a rich linguistic environment, in which their parents and/or other input models are fluent speakers of the language and provide input which exhibits the full range and regularity of processes and structures of a natural language. As Chomsky (1965, 1979, 1981) has noted, even a normal linguistic environment is impoverished from the point of view of deterministically indicating the nature of the underlying rule system. In this sense, then, studies of ordinary language acquisition are actually studies of language learning under conditions of impoverished input. However, in such normal circumstances, the input data do exemplify all of the types of structures included in the target language, and also exhibit a high degree of regularity in their usage in definable contexts. Chomsky's point may be pursued a step further by seeking cases where the input does not provide even the usual degree of consistency or complexity. Studies of children acquiring languages in such conditions can allow us to ask whether children are so biased in the way they learn languages that they may acquire an output language which is quite differently organized than the input language on which it is based. Several types of studies attempt to address this issue, including studies of linguistically isolated children and studies of children acquiring reduced pidgin and creole languages.

The most extreme cases of reduced linguistic input are those in which children receive no input language at all during the relevant language learning period. Not surprisingly, most cases of this degree of reduced linguistic input also involve severe cognitive, perceptual, and social deprivation as well. The well-documented cases of feral children (Itard, 1932; Lane, 1979; Zingg, 1940)—children thought to be raised in the wild without human contact—and Genie (Curtiss, 1977; Fromkin, Krashen, Curtiss, Rigler, & Rigler, 1974)—a case of severe child neglect where a young girl was virtually deprived of linguistic input from infancy until after puberty—have shown that complete linguistic deprivation during the early years results in severe language deficiency. Indeed, studies of these cases typically include no mention of

whether linguistic communication developed during the period of deprivation; instead these studies focus on the question of successful language learning once immersion in a normal linguistic environment occurs. Presumably the development of a linguistic system is exceedingly unlikely when there are not even other human social partners with whom to communicate. In addition, of course, it is difficult to assess the effects of impoverished linguistic input separately from the more general psychological effects of extended social deprivation.

Cases of reduced linguistic input without apparent social compromise arise from circumstances in which the child's primary linguistic models cannot, for some reason, favorably model the language, but in which the child is otherwise not deprived or isolated. The reduced input experienced by deaf children with no conventional linguistic input, children of immigrants, and children of pidgin speakers may reveal the limits under which language learning may occur.

1.1.1. Deaf children with no conventional linguistic input

Perhaps the most extreme cases of linguistic deprivation without significant social compromise are studies of deaf children who experience no conventional linguistic input. The parents of these profoundly deaf children have chosen to educate them through the oral method, which relies upon speech and lipreading and prohibits the use of signed language input. Goldin-Meadow and her colleagues (Feldman, Goldin-Meadow, & Gleitman, 1978; Goldin-Meadow & Feldman, 1977; Goldin-Meadow, 1978, 1982, 2003; Goldin-Meadow & Mylander, 1984, 1990, 1998) have studied profoundly deaf children of hearing parents raised in such circumstances. By the parents' choice, these children are not exposed to signed language input. In addition, their profound deafness prevents them from successful acquisition of spoken language, despite extensive oral training. Although this situation might appear to be socially depriving, the children are raised in supportive family environments and seem to be socially well adjusted. What is striking is that these children will devise their own gestural communication systems (known in the deaf community as "homesign" systems) for use with their family members. Goldin-Meadow and colleagues have shown that these self-created communication systems exhibit structural regularities characteristic of early child language: somewhat consistent gesture (word) order, the use of recursive structures (such as embedding one phrase or clause inside another), and gesture-internal morphology. Though not as complex as full-blown languages, these homesign systems feature some of the essential properties of natural language. This research suggests that, in the absence of conventional linguistic input, children can develop a language-like system. However, the fact that homesign systems studied thus far are not as structurally complex as full natural signed languages (e.g., American Sign Language, Chinese Sign Language) indicates that the linguistic environment plays a significant role in the development of certain linguistic properties.

1.1.2. Children of immigrants

Children of immigrant families could, under appropriate circumstances, provide important evidence regarding the acquisition of language from reduced or degraded input. It is widely known that children born to immigrants develop greater fluency in

the language of the host country than their parents, who often show inconsistent and fragmentary control over many structures of their late-learned language. However, to our knowledge, there are no studies of children for whom this type of parental input is the sole input for language acquisition. Children of immigrants are not usually exposed only to their parents' use of the host country's language; they have considerable contact with native speakers of the language outside the home and therefore presumably receive rich and regular input to this language. It would be extremely difficult to find a situation in which the child was isolated from native speakers and exposed only to her parents' imprecise use of the host country's language. For most children of immigrants, then, while linguistic input is varied, it is probably not reduced to the extent that it would provide an important source of evidence about unusual language learning.

1.1.3. *Children of pidgin speakers*

A *pidgin* is a communication system arising when speakers of many different languages have come into contact and do not share a common language (Holm, 1988). Traditionally, pidgins are described as having reduced and simplified grammars, with virtually no productive morphology. In place of grammatical elements such as tense or number marking, pidgins use full words or adverbial phrases when needed to indicate time or number, and many complex grammatical devices are simply absent or are inconsistently imported from the speaker's native language (DeCamp, 1971; Hymes, 1971; Koopman & Lefebvre, 1981; Muhlhausler, 1986; Sankoff, 1979; Sankoff & Laberge, 1973; Valdman & Highfield, 1980).

When pidgin speakers marry and have children, these children may be exposed to the pidgin as their native language. To a considerable extent, then, the children of pidgin speakers experience reduced and inconsistent linguistic input. Nonetheless, the structure of the children's speech has been claimed to be more complex than the adult pidgin (Bickerton, 1981; Koopman & Lefebvre, 1981). The children's version of the pidgin, called a *creole*, shows greater structural regularity and complexity than the antecedent pidgin from which it was derived. Creolization has attracted the interest of language researchers because of the claim that children's output differs markedly from the reduced and inconsistent input to which they were exposed.

However, creolists disagree regarding the source of this structural expansion, and also regarding whether this expansion is unique to children. Based on data collected from Tok Pisin, a pidgin language spoken in Papua New Guinea, Sankoff (Sankoff, 1979; Sankoff & Laberge, 1973) and Muhlhausler (1976, 1980, 1986) have argued that structural expansion is observed among adult pidgin speakers as well as children and suggest that adult-child differences may not be a necessary feature of creolization. Rather, they propose that elaboration is a social phenomenon: linguistic expansion is related to the increasing demand for functional complexity and can be introduced by both adults and children.

Other researchers contend that it is the influence of surrounding languages that contributes to creole genesis (see DeGraff, 1999a, 1999b; Muysken & Smith, 1986, for reviews). The structure of the emerging creole is said to be a product of integrating features from superstrate and substrate languages present during the

period of creolization. Most creolists would agree, however, that creole grammars are affected by both universal linguistic constraints and surrounding language factors.

Bickerton (1981, 1984, 1986, 1987, 1988, 1999) has advocated the view that *true* creole grammars are developed exclusively by children. He agrees that Tok Pisin is a stabilized pidgin which has been extended by adults as well as children; but the existence of extension under such circumstances does not refute the possibility that, in the presence of more reduced pidgins, children are capable of sudden and dramatic language change. Bickerton's own research focuses on creolization from an unstable early pidgin. He contends that under these circumstances children have the ability to exercise an innate capacity to restructure their input quite radically, within one generation. Bickerton claims that creoles exhibit grammatical devices such as sentence embedding, aspect marking, relative clauses, word order, and productive morphology, even when their antecedent pidgins lack such structures. Bickerton's "language bioprogram hypothesis" asserts that these "innovative aspects of creole grammar are inventions on the part of the first generation of children who have a pidgin as their linguistic input, rather than features transmitted from preexisting languages (1984, p. 173)." He attributes the increase in linguistic complexity to an innate mechanism present only in child learners.

One concern with the available evidence on creolization is that it comes not from studies of child language acquisition, but from comparisons of the languages spoken by two groups of adults: the pidgin speakers of one generation versus the creole speakers of another. For example, Bickerton's evidence comes from comparing 90-year-old speakers of Hawaiian Pidgin English (HPE) and 70-year-old speakers of Hawaiian Creole English (HCE); he must assume that the current structure of HPE represents the input received by HCE learners when they were children. While Bickerton notes this problem and makes a compelling argument for his interpretation, one cannot be certain that the structural complexities observed in HCE speakers result from an innate program active during childhood some 60–70 years ago, or precisely what linguistic input was received by these learners at the relevant time. Indeed, until recently, virtually no data have been available anywhere in the creole literature that examine this type of early creolization while it is actually in progress. There has therefore been no direct evidence in this literature that the child, in the face of reduced linguistic input, changes or restructures it into a more complex output, or that provides detailed insight into how such change might occur.

In recent years, there has been a unique opportunity to observe the ongoing creolization of a sign language in Nicaragua (Kegl & Iwata, 1989; Kegl, Senghas, & Coppola, 1999; Senghas, 1995; Senghas & Coppola, 2001; Senghas, Coppola, Newport, & Supalla, 1997), which has begun to provide us with evidence that child learners may indeed be responsible for such language change. Nicaraguan Sign Language has been forming since about 1980, when deaf children and adults were first brought into contact with one another as public education for the deaf was introduced in Managua. Since that time, children have continually entered the deaf community that this school and a nearby deaf club have created, and the language has begun to expand and change (see Kegl et al., 1999; Senghas et al., 1997, for a description of

some of the grammatical devices that are gradually appearing). Senghas (1995) and Senghas and Coppola (2001) have shown that the increase in speed of signing and the addition of spatial grammatical devices (typical of other sign languages of the world) appearing in the language are in fact produced among the young children of the community.

Creole studies have thus provided us with the notion that child speakers may have a special capacity to surpass reduced or impoverished linguistic input, introducing linguistic complexity without specific exposure to the relevant structures. However, in most creolization situations, the pidgin is not the only language to which the children are exposed. Creole speakers are typically exposed to other full-blown languages and may be imposing previously or concurrently acquired linguistic knowledge onto the structure of the creole they develop. In addition, even when this is not the case (as in the ongoing creolization process of Nicaraguan Sign Language), we do not have access to the precise linguistic (or gestural) input of individual children, so that we might trace the changes individual learners impose on their input and the process by which they execute changes.

In sum, studies of creolization and of homesign suggest that young language learners may introduce systematicity into their developing linguistic systems without input to such regularity or complexity. However, much remains unknown about the limits on these processes, and about the precise ways in which the input data participate.

In the present study, we offer data that address this same issue. Our study details the learning of a language entirely from reduced and inconsistent input, and compares the child learner's attained competence to the actual input he receives. By comparing the child's output directly to the input, we can determine whether, and how, innovation or restructuring occurs. Through these means we will hopefully understand better the mechanisms by which such restructuring of reduced input may occur.

1.2. Current study

The American Deaf community provides a unique opportunity to observe children exposed to variations in their linguistic input. Less than 10% of the deaf community are native signers—children of deaf parents exposed to American Sign Language (ASL) from birth. Native signers acquire ASL in a normal fashion, parallel to hearing children learning spoken language, and by middle childhood attain native fluency in the language (see Lillo-Martin, 1999; McIntire, 1994; Newport & Meier, 1985, for reviews). In contrast, late learners of ASL lack much of the syntactic and morphological complexity used by native signers, and are inconsistent in their linguistic performance overall (Emmorey, 1991; Mayberry & Eichen, 1991; Mayberry & Fischer, 1989; Mayberry, Lock, & Kazmi, 2002; Newport, 1990, 1991; Newport & Supalla, 1980). An important case to study, then, is the next generation: a child acquiring ASL as a native language, but whose only input to ASL comes from his late-learning parents. This child, like a creole speaker, learns his primary language from a reduced and inconsistent source.

This study focuses on one such child, Simon, a 7-year-old deaf child of deaf parents. Simon's mother and father are both late learners of ASL and are Simon's only input to ASL. As we discovered shortly after the onset of this investigation, this particular family constellation is quite rare. Deaf children of deaf parents are often members of extended families which include several generations of deaf relatives and are therefore typically exposed to fluent native ASL early on. Simon's situation is unusual in that no deafness is known in either parent's family other than the parents themselves. Moreover, both parents are late learners of ASL, due to the fact that their hearing parents exposed them at a young age only to oral education at schools where no one signed. Both parents learned ASL only as teenagers, but have been using it ever since as their primary method of communication and the language used within their family.

Simon's parents' imperfect ASL is his only source of input to the language. The topic of this study is how Simon acquires ASL from such a source, and in particular whether he reproduces the imperfections of his input, or rather introduces greater consistency and structure than his input provides.

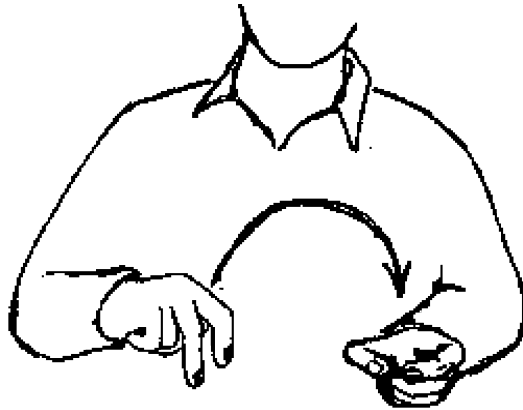
In the present study, we focus on verb morphology because previous studies have shown that the morphology of ASL verbs of motion is particularly complex and is among the most difficult of structures to master in ASL (Kantor, 1980; Newport, 1981; Schick, 1987, 1990; T. Supalla, 1982, 1986). Unlike English, ASL is a morphologically complex language, with word formation similar to polysynthetic spoken languages. A typical ASL verb of motion can contain seven or more independent morphemes articulated simultaneously. ASL verb morphology is thus complex enough that highly systematic input to this system would seem necessary for it to be successfully learned. The effect of inconsistent input to this morphological system is the focus of the present study.

2. Method

The study examines 7-year-old Simon's performance on an American Sign Language productive morphology task. We compare Simon's performance with that of his own late-learning parents and also with eight deaf children of native signers. Of interest is whether, and how, Simon's ASL performance is affected by the highly inconsistent input that has been his only exposure to ASL. In addition, we will examine the process by which Simon analyzes this input.

2.1. *The structure of verbs of motion in ASL*

As mentioned above, verbs of motion in ASL are morphologically quite complex. A single verb of motion consists of as many as seven distinct morphemes, which indicate such things as the class of objects involved in the event, the type of path traversed by the moving object, the manner of motion along this path, and the spatial relationship between the moving object and other landmarks (T. Supalla, 1982). (In English, these aspects of an event of motion are conveyed by a verb plus various adverbial and prepositional phrases.) Fig. 1 includes a brief description of the seven



Seven Morpheme Categories of ASL Verbs of Motion

Root = Path along which object moves

Orientation = Orientation or direction in which the object moves

Manner = Manner in which the object moves

Location = Locative relationship of moving object to secondary object

Position = Position of the secondary object with respect to the central object path

Central Object Handshape = Class (category or size and shape) of the moving object

Secondary Object Handshape = Class (category or size and shape) of the secondary object

Fig. 1. ASL verb of motion example with a description of seven morpheme categories (based on T. Supalla, 1982).

morpheme categories within ASL verbs of motion on which we focus in our analyses: five motion/location morpheme categories (ROOT, ORIENTATION, MANNER, LOCATION, POSITION), and two handshape morpheme categories (CENTRAL and SECONDARY OBJECT). These seven types of morphemes constitute the primary morphology of ASL verbs of motion (T. Supalla, 1982).

Every ASL verb of motion requires at least a ROOT and CENTRAL OBJECT morpheme; these are obligatory. The ROOT morpheme indicates the path along which the object moves, for example a straight line or a circle. The CENTRAL OBJECT morpheme is a classifier, that is, a morpheme indicating the category (e.g., HUMAN or VEHICLE) or shape (e.g., CYLINDRICAL) of the moving object. Like verb classifiers in many spoken languages, this morpheme in ASL must agree with the subject noun of the sentence. Thus, a description of a car moving forward along a linear path would be expressed in ASL by a sentence (“CAR LINEAR + VEHICLE”) in which the subject noun CAR is followed by a verb of motion that includes a LINEAR ROOT morpheme (meaning “moves along a linear path”) and a VEHICLE CENTRAL OBJECT classifier morpheme. If the moving object has a special manner of motion along its path, for example bouncing or rolling, a MANNER morpheme would be included in the verb as well. Similarly, if the moving object has a special orientation or direction of motion, for example moving backwards

or uphill, an **ORIENTATION** morpheme would be included. Finally, if the event includes a secondary object, relative to which the moving object moves, the verb of motion would also include a classifier for the **SECONDARY OBJECT**, a **POSITION** morpheme indicating the spatial relation of the secondary object relative to the path (e.g., at the beginning or end of the path), and a **LOCATION** morpheme indicating the spatial relation of the central object relative to the secondary object at their point of contact (for example, inside or on top of it). Fig. 1 illustrates an example of a moderately complex verb of motion, with five morphemes; this verb would be used within a sentence describing a doll jumping into a hoop. All of these types of morphemes, and the particular morpheme values used in ASL, appear in many spoken languages that, like ASL, have morphologically complex verbs of motion. However, in ASL, unlike spoken languages, the morphemes are combined in a more simultaneous rather than sequential fashion, and the forms of many of the morphemes (though not all) are more iconic than their analogues in spoken languages. (For a discussion of verbs of motion in ASL compared with spoken languages, and an argument that these are morphemes rather than icons in ASL, see T. Supalla, 1982.)

2.2. *Materials and procedure*

Participants' control over this particular domain of morphology was evaluated by administering an elicited production test. The Verbs of Motion Production (VMP) test was developed by T. Supalla (1982).¹ The VMP test is composed of 120 short filmed events of people and objects that move in varying paths and manners of motion, for example, a doll jumping into a hoop (an event corresponding to the linguistic example depicted in Fig. 1), or a robot moving past a motorcycle. The animated film segments, each 1–2 s in length, are shown one at a time to the participant. After each filmed event the participant is asked to describe what happened, using ASL, and the videotaped responses are later scored by a trained native signer on the seven types of ASL morphemes described above. The VMP test items are each constructed to elicit a single verb of motion and are balanced over the test so that roughly an equal number of items will test each morpheme of interest.² Over the entire test, the participant's control of individual morphemes and morpheme categories can be evaluated. The experiment is conducted in the participant's home by a native-signing experimenter, and the session is videotaped for later analysis.

¹ A revised and shortened version of the VMP test is available in T. Supalla et al. (in press).

² Since the morpheme categories vary in whether they are obligatory and must appear in any verb of motion (e.g., **ROOT**) or appear only in those expressing certain types of marked events (e.g., **MANNER**), the morpheme categories likewise varied in how many VMP test items required their use. Moreover, morpheme categories vary in how many individual morpheme contrasts are widely used in ASL, and therefore the number of individual morphemes tested was also varied. However, within each morpheme category, approximately an equal number of items tested each of the individual morphemes. Over the 53 individual morphemes, 32 were tested by 5–24 test items in the VMP, while 21 were tested by 4 or fewer test items.

Each morpheme in the participant's verb response is scored for accuracy with respect to previously established targets for native ASL usage.³ The targets were determined by T. Supalla (1982) through linguistic analyses of verbs of motion in ASL, and were subsequently verified by testing native ASL signers (Newport, 1990; T. Supalla et al., in press). Over the 120 test items, the participant's consistent and correct use of this morphology can be examined in terms of: total score (the number of morpheme tokens, out of a possible 479 on the test, that the subject produced correctly); score on each of the seven morpheme categories (the number of morpheme tokens produced correctly, for all morphemes within a morpheme category); and score on each of 53 individual morphemes (the number of morpheme tokens produced correctly, for all tokens of a single morpheme). In addition, type and frequency of errors can be determined.

Because the filmed events are novel and sometimes funny, the Verbs of Motion Production test is enjoyable for both adults and children. In addition, the native-signing experimenter engages each participant in informal spontaneous conversation before the VMP test is administered. Both of these factors insure that ASL is the language being used by the participant in the testing situation. Our goal was to evaluate the participants' control over the morphology of ASL verbs of motion.

2.3. *Participants*

2.3.1. *Simon*

Simon is a 7-year-old profoundly deaf child of deaf parents. He is the oldest child in his family and has one younger sibling, who is hearing. His hearing loss is so profound that he has been unable to acquire spoken English to native fluency. Simon attends a local public school, in the suburbs of a large metropolitan city, which has placed him in a self-contained classroom for deaf and hard-of-hearing children; he is mainstreamed with hearing children for Physical Education and Art classes and recess. None of Simon's classmates or schoolmates has deaf parents, and none was observed using ASL when classroom and playground observations were conducted on multiple occasions. As best we can tell, they do not know any ASL. His teacher is hearing and communicates with her students by using a manual code for English simultaneously articulated with spoken English (called Total Communication or Simultaneous Communication). Manual codes for English contain no ASL morphology. They are comprised of basic (uninflected) sign vocabulary borrowed from ASL, and rely upon a set of invented "signs" to represent the details of English morphology.⁴ All propositions are expressed in the word

³ Scoring was performed by J. Singleton, a hearing native signer of ASL. Reliability of scoring between JS and two other coders, both fluent in ASL, on various subsets of the data was 95% or better.

⁴ S. Supalla (1990) has suggested that these invented morphemes, which are intended to represent bound morphemes in English, are, in fact, structurally equivalent to free morphemes in natural signed languages. He argues that deaf children are therefore unable to parse the Signed English stream into the morphological components intended by its designers, leading to its being unlearnable for most deaf children.

order of spoken English. The goal of this communication system is to represent the structure of spoken English in the visual/gestural medium. Several researchers have questioned whether these manual codes successfully impart the structure of English to deaf children (Johnson, Liddell, & Erting, 1989; Marmor & Petitto, 1979; S. Supalla, 1991). In any case, this method of communication does not model ASL or its grammatical structures.

The point here is that neither Simon's teacher nor his schoolmates are potential input sources to ASL linguistic structure, in particular, verbs of motion morphology. Simon's late-learner parents are his primary linguistic models to ASL syntax and morphology.

Despite this restricted linguistic environment, Simon appears to be normal with respect to his social and emotional development. From classroom observations we could see that Simon was bright, motivated, and was treated as the class leader by his peers. With only few exceptions, Simon led the games being played and was the first to raise his hand when the teacher asked the class a question. When we asked Simon about the signing of his classmates and teachers, he modestly confirmed that their signing was "different" from his own.

Judging from our extensive interviews with Simon, his parents, and his teacher, then, we are confident that virtually all of Simon's exposure to ASL comes from his late-learner parents. Indeed, the only contact with ASL that we know Simon has had, other than from his parents, is when a native ASL signer from our laboratory visited the home once every six months for approximately 1 h, as part of the longitudinal study of his development. However, this limited interaction with an ASL signer (for a total of 2 h per year) is extremely unlikely to have had substantial impact on Simon's signing and cannot be considered a significant part of his primary linguistic input. Furthermore, as we will show, results of our testing (specifically, certain missing and unusual handshape classifiers that Simon and his parents all exhibit) provide compelling evidence that Simon has been effectively isolated from native or near-native models of ASL (or at least that such models have not contributed significantly to Simon's acquisition of ASL). In our interviews with the parents, they described their social life as being primarily family-centered, including hearing extended family members, and some interactions with an "Oral Deaf" Club. Members of this social club rely primarily on oral communication and speech reading along with some signing to support their speech. The club activities are mostly for adults, with occasional holiday gatherings for the members' children (e.g., Christmas party or Easter egg hunt). Based on these interviews and the demographics of the American deaf community (90–95% nonnative signers; Schein & Delk, 1974), we believe that Simon has had little, if any, exposure to native signers, even on an infrequent basis.

2.3.2. *Simon's parents*

Both of Simon's parents are profoundly deaf. Neither learned ASL until after the age of 15 (mother 15; father 16) due to having nonsigning hearing parents and attending oral schools where sign language was prohibited. Although they had extensive oral training, neither acquired spoken English to native fluency, due to their

profound hearing losses.⁵ Both of Simon's parents began to learn ASL after chance meetings with some deaf teenagers who signed. From that point on, they embraced sign language and as adults now use ASL as their preferred and primary means of communication with each other and with their children; at the time of data collection, they had each been signing for almost 20 years. Their social circle is fairly limited. As noted above, they attend some activities at an "oral deaf" club, presumably because they identify with its members who attended similar oral schools. They also visit with hearing extended family members, using speech along with signing to communicate. The primary language of the nuclear family is ASL, and they are Simon's primary linguistic source for ASL.

2.3.3. *Adult signers*

For purposes of comparison with Simon's parents' data, the Verbs of Motion Production test was administered to a group of eight native-signing adults and eight late-learner adults (post-pubertal acquisition of ASL). With these data we can establish native and late learner performance criteria which will allow us to evaluate the quality of Simon's parents' signing. All native and late-learner adults included for comparative purposes were profoundly deaf and have used ASL as their primary means of communication for at least 10 years.

2.3.4. *Child signers*

Because Simon is only 7 years old, it may not be appropriate to compare him to adult native signers, as we know children continue to acquire some aspects of ASL verb morphology into late childhood (Lillo-Martin, 1999; Newport & Meier, 1985). Accordingly, VMP data were collected from a group of eight native-signing children, all of whom are approximately the same age as Simon, and whose parents are themselves Deaf native signers. These children (Native of Native, abbreviated NN) receive fluent, rich, and consistent ASL input. The eight NN children ranged in age from 6;1 to 10;10. A rank order correlation was performed between their ages and their morpheme category scores on the VMP to determine whether the children formed an approximately homogeneous age group despite the variation in their exact ages. In all morpheme categories, the rank order correlations were not significant (all p values $>.10$), suggesting that the eight children do form a single age group with respect to their ASL verbs of motion skills. Simon's scores are compared to the performance of this group of NN learners, to determine whether the reduced quality and consistency of Simon's linguistic input has effects on his linguistic output.

⁵ Although no formal measures of their spoken English abilities were made, both parents' attempts to speak to hearing relatives, neighbors, and their hearing son were observed. In these contexts, neither parent demonstrated fluent or grammatical speech. See Wilbur (1987) and Quigley and Kretschmer (1982) for extensive data on the difficulties of deaf individuals with English syntax and morphology.

3. Results

We will begin by presenting a quantitative description of Simon's linguistic input. By comparing Simon's parents' performance to that of other adult signers (both native and late learners of ASL), we can characterize the quality of input Simon receives. We will examine the parents' accuracy, consistency, and the nature of their errors on the Verbs of Motion Production (VMP) task. Second, we will present Simon's own performance on the same task and compare Simon's signing to his parents and to other child signers who receive rich native input to ASL. Finally, we will provide a detailed analysis of Simon's input and output patterns to further understand the nature of language learning from reduced and inconsistent input.

3.1. Parents' overall performance

The upper portion of Table 1 presents the percent correct VMP test results for each of Simon's parents, and the means and standard deviations for the native and late-learner adult signing groups. Fig. 2 pinpoints each parent's percent correct score against the 95% confidence intervals around the (A) native signer and (B) late learner means for each morpheme category. As can be seen in Fig. 2A, Simon's parents' scores fall outside of the 95% confidence interval around the adult native signers' mean for each morpheme category. In contrast, as shown in Fig. 2B, their scores fall well within the 95% confidence interval for the adult late learners of ASL for all morpheme categories. In short, they sign like other late learners, using motion and location morphemes correctly only about 70% of the time, and handshape morphemes correctly only about 45% of the time.

Although Simon's input is inconsistent and errorful overall, it is worth noting (see Table 1) that his input is somewhat better in motion/location categories than in handshape categories. The range of scores for the parents on motion/location morpheme categories is 65 to 83% correct, whereas it is only 37 to 46% correct for the two handshape morpheme categories.

3.2. Verbs of motion error types

When Simon's parents do not produce correct morphemes, what is the nature of their errors? They might, for example, always produce one of two forms, either the correct morpheme or a single alternative form; or they might either produce the correct morpheme or omit the morpheme from their verb. In either of these cases, Simon's input would be relatively consistent, even though not precisely the same as that received from a native signer. In contrast, it might be the case that the parents' errors are themselves extremely inconsistent, scattered among a wide variety of alternative forms, each of which is produced infrequently. This would provide quite a different pattern from which to learn ASL morphology.

One way to answer this question is to examine the types of errors produced by the parents. We have categorized these errors into three types:

Table 1

Means and standard deviations of motion/location (ROOT, ORIENTATION, MANNER, LOCATION, and POSITION) and handshape (CENTRAL OBJECT and SECONDARY OBJECT) morpheme categories by Simon and his parents, native and late-learner adult ASL signers, and native child ASL signers

	Motion			Location		Handshape		Summary	
	ROOT (120)	ORIENTATION (37)	MANNER (40)	LOCATION (54)	POSITION (54)	CO (120)	SO (54)	Motion/ location (305)	Handshape (174)
Native adults ($n = 8$)	.94 (.03)	.90 (.05)	.90 (.06)	.97 (.03)	.98 (.02)	.84 (.06)	.80 (.10)	.94 (.02)	.82 (.06)
Father	.70	.76	.75	.65	.65	.46	.43	.69	.45
Mother	.77	.76	.83	.70	.68	.45	.37	.75	.42
Late learners ($n = 8$)	.74 (.15)	.76 (.12)	.73 (.14)	.70 (.25)	.75 (.25)	.57 (.17)	.50 (.26)	.74 (.17)	.55 (.20)
Simon	.87	.84	.87	.91	.91	.46	.59	.88	.50
NN children ($n = 8$)	.84 (.01)	.80 (.08)	.86 (.05)	.87 (.09)	.88 (.08)	.69 (.10)	.67 (.12)	.81 (.11)	.69 (.10)

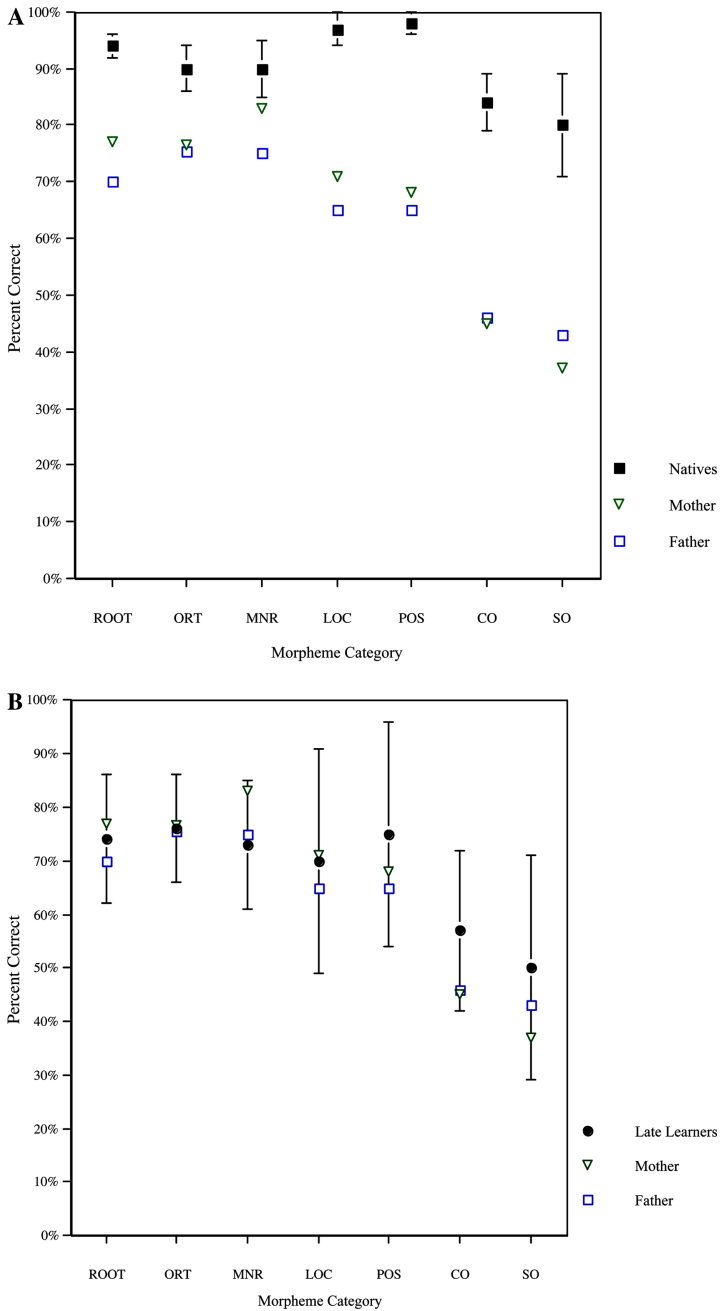


Fig. 2. (A,B) Simon's parents' VMP percent correct scores for each of seven morpheme categories presented in relationship to the 95% confidence interval around (A) the mean VMP performance of eight native ASL signing adults, and (B) the mean VMP performance of eight adult late learners of ASL.

1. *INCORRECT MORPHEME*. In this type of error, the signer substitutes an incorrect morpheme for the required ASL morpheme (e.g., using a *LINEAR* root instead of a *TURN* root).
2. *OMITTED MORPHEME*. In this type of error, the signer does not produce the required morpheme and does not replace it with an alternative morpheme. Consequently, the response omits expression of the semantic feature presented in the stimulus event.
3. *SPLIT VERB: SEPARATED AND/OR INCORRECT MORPHEMES*. The final type of error is quite a bit more complex. Recall that ASL verbs of motion are comprised of up to seven morphemes which are articulated simultaneously. For example, a single verb stem is composed of a motion, an orientation, and a handshape, and each of these is a morpheme indicating a single aspect of the event. However, late learners frequently produce a type of error in which, instead of articulating the required morphemes simultaneously, the signer produces a sequence of separate signs. Each of the signs in this sequence may express the meaning of one of the morphemes required in the verb of motion. For example, if the target showed a vehicle moving uphill (normally represented by a single complex verb of motion with three simultaneously articulated morphemes *VEH + LINEAR + UPHILL*), a *SPLIT* error might contain *CAR*, *MOVE*, *STRAIGHT*, *UPHILL* as separate lexical signs. This type of error thus involves replacing the morphology of verbs of motion with a periphrastic (phrasal) construction.

This type of error provides particularly confusing input regarding the structure of verbs of motion in ASL. If events of motion were always expressed in this way, the child would learn that the handshapes, motions, and orientations of each of the signs in this sequence do not carry their own meanings; rather, meaning is conveyed lexically, by each sign as a whole. This is indeed the way verbs of motion are organized in many languages, including English. However, when sequences of this kind are unpredictably mixed with sentences containing verbs composed of individual morphemes (e.g., Simon's mother signed *WOMAN PASS DOG Z-TIP + LINEAR*), the learner receives particularly inconsistent input information: *SPLIT* sequences include several signs, each of which has a distinct handshape, a distinct motion, a distinct orientation. When mixed with verbs whose handshapes, motions, and orientations map consistently onto classification, movement, and orientation contrasts, these sequences provide an especially noisy and potentially misleading source of input for learning.

Fig. 3 presents the proportion of errors of each of these three types, for Simon's mother and father on motion/location morphemes. As this figure shows, the parents' errors are apparently not focused on producing only one alternative form. Each of the three error types occurs relatively frequently. Moreover, for both of Simon's parents, *SPLIT* verbs are the most frequent type of error produced (accounting for approximately half of their error types), followed by *INCORRECT* and *OMITTED MORPHEMES*. A more detailed examination of these errors revealed that there were few consistencies among them. Except as noted below, the parents did not consistently produce specific alternative forms, either within their *INCORRECT*

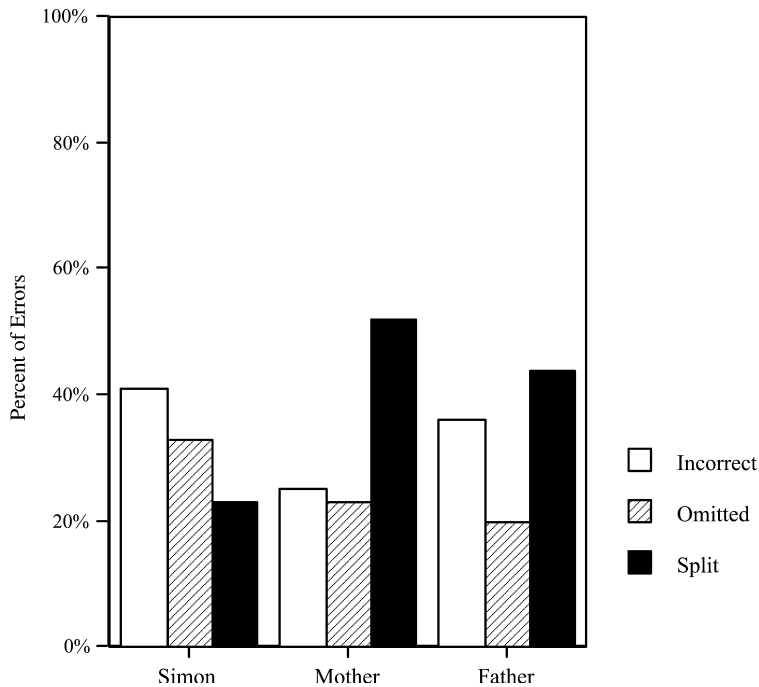


Fig. 3. Proportion of total motion/location errors falling into INCORRECT, OMITTED, and SPLIT error types for Simon and his parents.

MORPHEMES or their SPLIT verbs. In accord with other data on the nature of late learners' performance (Johnson, Shenkman, Newport, & Medin, 1996), errors were relatively unpredictable and were scattered among a variety of infrequent and distinct alternative forms.

3.3. Summary of Simon's input

To summarize, Simon's input to the structure of ASL verbs of motion consists of a mixture of correct morphemes, omitted morphemes, incorrect morphemes, and lexical strings which replace the correct morphology. For motion/location contrasts, correct ASL morphemes are used with 65–83% consistency, with lowered accuracy mostly due to the parents' tendency to express the same meaning inconsistently, in lexical phrases (SPLIT verbs). For handshape morphology, the input accuracy drops to 37–46%. In short, Simon receives an input corpus that is noisy, inconsistent, and therefore potentially difficult for a learner to analyze.

3.4. Simon's overall performance

We now ask how Simon's control over ASL morphology is affected by his inconsistent input, by comparing his productions in the VMP test to deaf children

of similar age who receive native ASL input, and to his parents. Returning to Table 1, the bottom portion presents the percent correct VMP test results for Simon, and the means and standard deviations for the group of native signing deaf children with native input (NN, Native of Native).

Fig. 4 presents Simon's percent correct scores plotted against the 95% confidence intervals around the NN group means for each morpheme category. As can be seen, Simon's five motion/location category scores, ranging from 84 to 91% correct, fall well within the NN children's 95% confidence interval. Examining Table 1 in its entirety, it is impressive to see that Simon's motion/location scores exceeded his parents' scores by almost 20% points for each category. Fig. 5 shows Simon's totaled motion/location VMP score compared to his parents' scores and also to his NN peers. Note that Simon, at age 7, surpasses his parents' motion/location performance and looks remarkably like his NN peers.

On the two handshape categories, however, the outcome is somewhat different. Simon's CENTRAL OBJECT handshape performance falls outside the NN children's confidence interval (see Fig. 4). On SECONDARY OBJECT handshape, Simon's score of 59% correct is just barely within the 95% confidence interval around

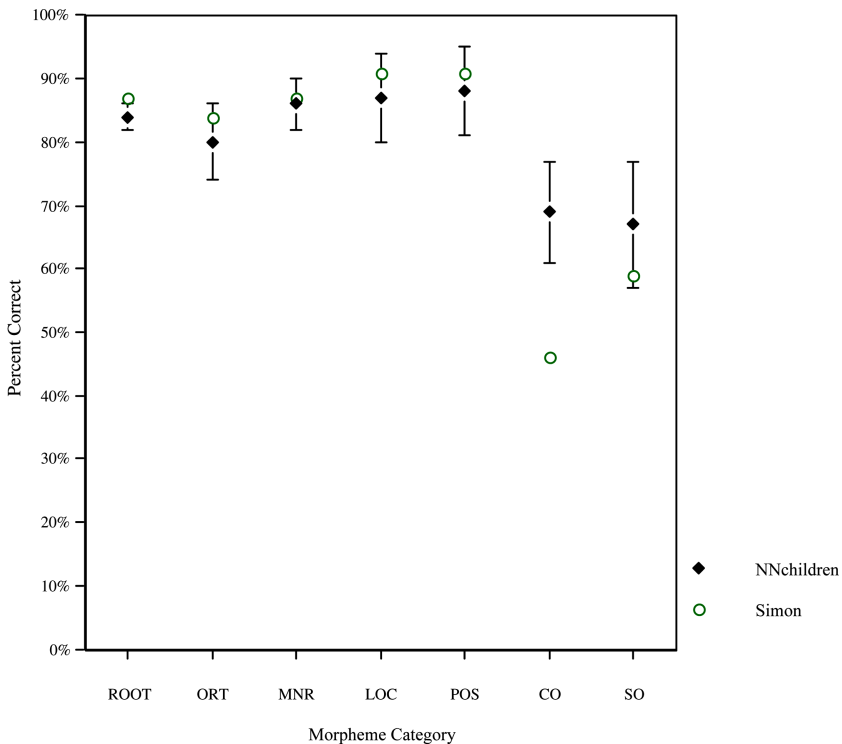


Fig. 4. Simon's VMP percent correct scores for each of seven morpheme categories presented in relationship to the 95% confidence interval around the mean VMP performance of eight native (NN) ASL signing children.

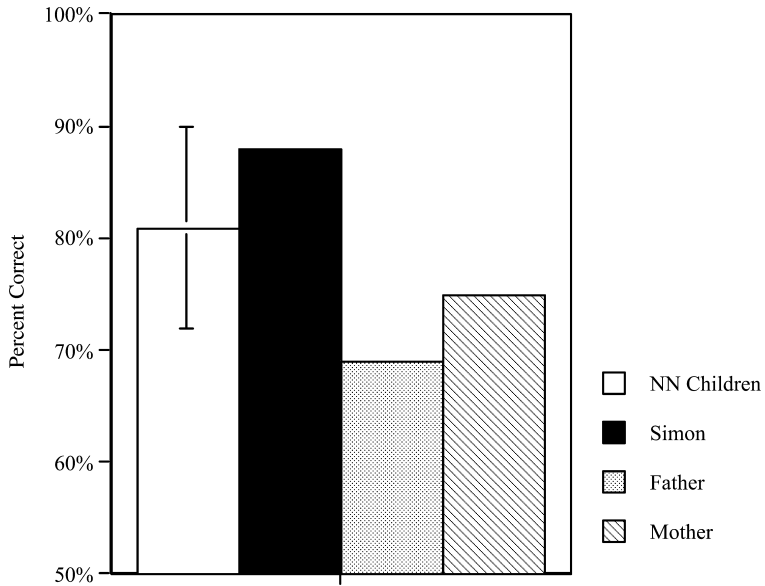


Fig. 5. Simon's mean motion/location (across five morpheme categories) VMP percent correct scores compared to his parents and his native (NN) ASL signing peers.

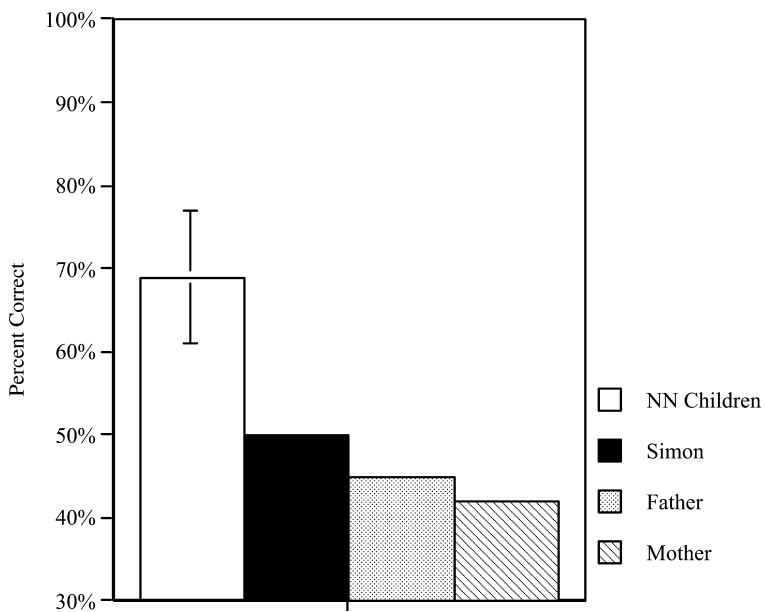


Fig. 6. Simon's mean handshape (across two morpheme categories) VMP percent correct scores compared to his parents and his native (NN) ASL signing peers.

the NN children's group mean. As compared to the motion/location categories, in the two handshape categories Simon performs at lower levels of correctness (46–59% correct). Fig. 6 shows Simon's totaled handshape VMP score, compared to his parents and to his NN peers. In terms of this total, he is substantially below his NN peers and indeed scores at a level more similar to his parents. Thus it appears that Simon does not improve upon his input in the handshape domain to the extent that he does in motion/location categories. One possibility is that Simon and his parents have developed a linguistic system for handshape that differs significantly from ASL, a result which would explain the lowered accuracy for all three individuals. This alternative will be explored in a later section.

To understand these results more fully—how Simon overcomes the inconsistency of his input for motion/location categories, as well as why he may not do so to the same degree for handshape categories—we turn to a more detailed examination of individual morphemes and their input frequency patterns.

3.5. Analysis of motion/location morphemes

3.5.1. Frequency boosting

How does Simon surpass his linguistic input, particularly for motion and location morphemes? We suggested above, from examining the overall accuracy and error types, that while Simon's parents' productions contain substantial inconsistency, they appear to contain a particular *pattern* of consistencies and inconsistencies on which Simon's successful performance may depend. To see this pattern more clearly, we need to examine the data for individual morphemes.

Recall that the morpheme categories presented thus far (ROOT, ORIENTATION, and the like) consist of a number of individual morphemes that we examined in the VMP test. The ROOT category, for example, includes the individual morphemes LINEAR, JUMP, and several others. Table 2 presents the data for the ROOT morpheme category broken down into these individual morphemes. At this quite detailed grain, shown as an example, we can see that the overall pattern described thus far also characterizes the individual morphemes: For each morpheme, the parents predominantly produce the correct ASL form, but only 60–80% of the time. When they do not, their errors are scattered over a number of alternatives (for example, on the TURN target, alternatives produced included LINEAR, CIRCLE, LINEAR/ARC, and some SPLIT responses). Table 2 also shows that in each case Simon uses the parents' most consistent form, but with even more consistency than do his parents. For example, Simon's father and mother produce the correct LINEAR path morpheme 62 and 79% of the time, respectively, whereas Simon uses it 96% of the time in the 24 required contexts. We call this response pattern on Simon's part "frequency boosting," a pattern in certain ways like "overregularization" produced by young children whose normal input includes irregular forms (see Section 4).

To determine how widespread this frequency boosting phenomenon was over all the motion/location morphemes, we examined scores like those of Table 2 for each of the five motion/location categories (ROOT, ORIENTATION, MANNER,

Table 2

Illustration of Simon's "frequency boosting" pattern: Percent correct scores for Simon and his parents on ROOT and CENTRAL OBJECT morpheme types

Target value (number of targets*)	Percent correct		
	Father	Mother	Simon
<i>ROOT morpheme category</i>			
LINEAR (24)	0.62	0.79	0.96
JUMP (21)	0.71	0.81	0.91
PIVOT (9)	0.89	1.00	0.89
TURN (21)	0.76	0.81	0.86
COMPLEX PATHS (12)	0.67	0.42	0.83
LIN/TURN + MNR (21)	0.71	0.76	0.81
JUMP + PIVOT (12)	0.42	0.67	0.75
<i>CENTRAL OBJECT handshape morpheme category</i>			
Semantic classifiers			
VEH = BEDGE (15)	0.67	0.47	0.73
PLANE (9)	0.44	0.11	0.67
LEGS (28)	0.57	0.50	0.61
TREE (6)	0.17	0.00	0.17
Size/shape specifiers			
ZC (12)	0.17	0.42	0.67
BC (13)	0.54	0.62	0.38
ZHORIZ (8)	0.50	0.88	0.38
BFLAT (8)	0.63	0.13	0.25
ZVERT (5)	0.60	1.00	0.20

* This table includes only those morphemes with five or more test items in the VMP.

LOCATION, and POSITION) and determined how often Simon showed frequency boosting of his parents' usage, as compared with frequency matching or frequency reduction. Simon shows frequency boosting in most of the morphemes in the motion/location categories (13 out of 19 morphemes, $p < .001$ of this distribution by chance). In the few remaining morphemes (6 out of 19), Simon's score was either equal to or between his two parents' scores. In no case was Simon's score worse than the lower scoring parent.

Fig. 7A shows this phenomenon in a somewhat different way. In this scatterplot, we present Simon's percent correct scores for each of the individual morphemes within the motion/location categories, plotted against the same scores for each of his parents (mother = triangles, father = squares).⁶ The dashed diagonal line indicates where the points should fall if Simon were matching the probabilities of his parents' usage for each of the morphemes. The actual data do not fall on this diagonal. Rather, frequency boosting is quite evident visually: data points are widely distrib-

⁶ These data only include those morphemes tested by five or more items. Including morphemes tested by fewer items slightly obscures the relationship, due to less reliable data points.

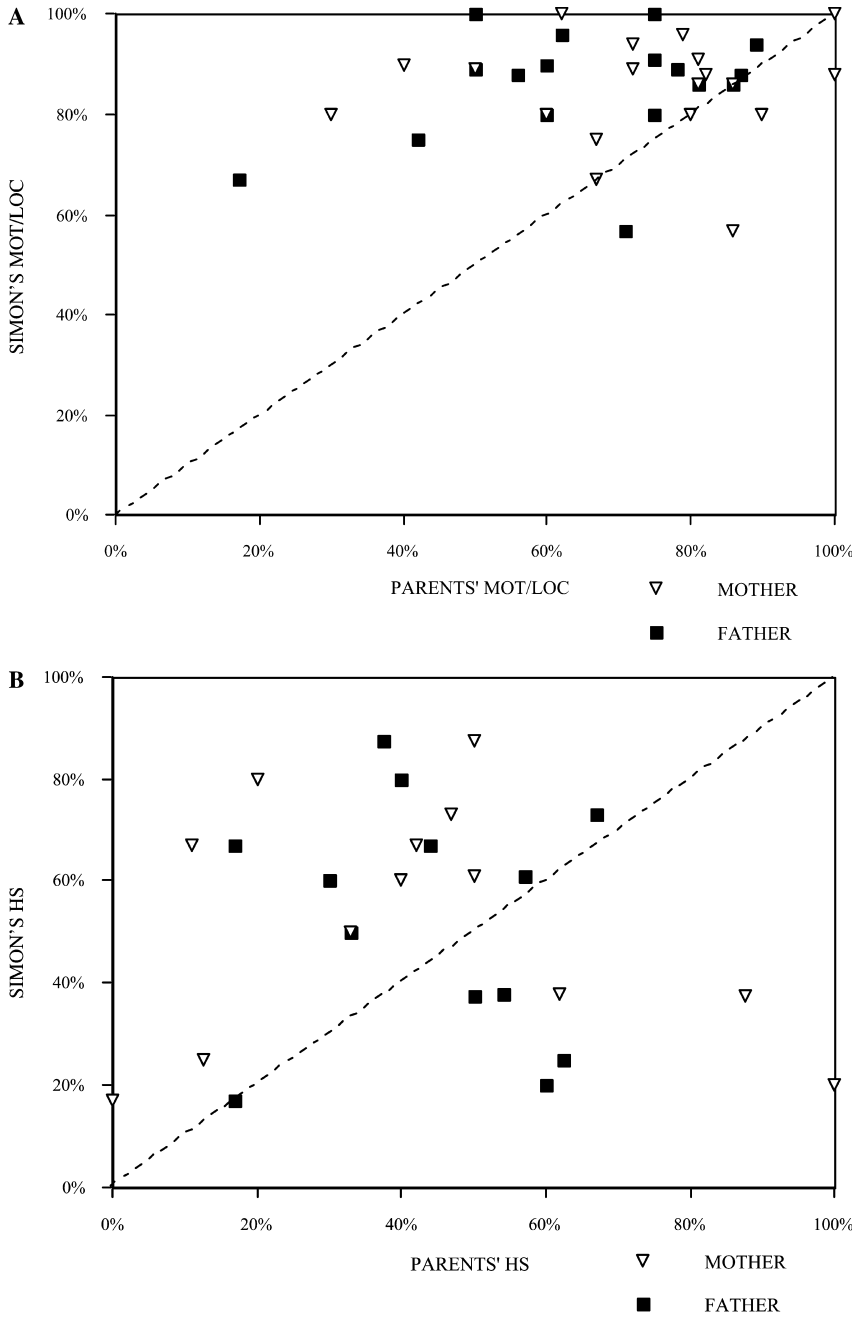


Fig. 7. (A,B) Simon's parents' percent correct scores (*x*-axis) plotted against Simon's (*y*-axis) on (A) individual motion/location morphemes, and (B) individual handshape morphemes. If the squares/triangles had fallen along the dotted diagonal line, it would mean that Simon was matching his parents' score for each morpheme (probability matching).

uted over values along the x -axis (parent's scores), but are all at the ceiling of the y -axis (Simon's scores). This is the frequency boosting phenomenon. Each parent exhibits overall lowered performance and considerable variability in accuracy from one morpheme to another, while Simon's responses are clustered primarily above 80% correct.

3.5.2. *Motion/location errors*

We can also ask what types of errors are produced by Simon as compared with his parents. We have already shown that Simon produces fewer errors than his parents (out of 305 individual motion/location morpheme contexts tested, Simon produces only 37 errors (.12), while his father produces 93 errors (.31) and mother 75 errors (.25)). We ask whether the errors he does make are of the same types and proportions as those of his parents, to see whether Simon acquires the irregularities that are prevalent in his input.

Simon's motion/location errors clearly differ from those of his parents' (see Fig. 3). For both of Simon's parents, SPLITs are the most frequent type of error, followed by INCORRECT and OMITTED MORPHEMES. In contrast, SPLITs are fewest among Simon's errors; overall, only 3% of his responses are SPLITs. Simon does not acquire the most common type of error produced by his parents. Instead, when he does not produce and boost their most frequent response, he usually either produces a related morpheme or omits the required morpheme.

This contrast between the common appearance of SPLITs in the parents' signing and their relatively rare appearance in Simon's signing indicates that Simon does not precisely mirror all the features of his input. It also, however, has another import: Simon's parents' use of SPLITs shows that they do not consistently construct their verbs of motion by combining morphemes to form a single verb. Rather, their signing varies between constructing verbs of motion from such morphemes and expressing the same meanings in lexical sequences. For each morphological context, simultaneously and sequentially organized (as well as correct and incorrect) morphemes appear to be in free variation with each other. In addition, the sequences of signs appearing in the parents' SPLIT responses do not appear to be syntactically well-structured phrases; rather, they are often haphazard, and ungrammatical, strings of signs. In contrast, Simon stays more consistently with a morphological, rather than a periphrastic, construction of his verbs.

3.5.3. *Summary*

For the motion/location morpheme categories, Simon has acquired a highly structured and consistent morphological system. He has apparently ignored the irregularities and inconsistencies in his parents' signing, and instead has extracted and overregularized those elements which appear with only moderate consistency in his input.

The means by which he has accomplished this is apparently by locating, and boosting the frequency of, those forms that are most consistently used by his parents. Because the more consistently used morphemes in Simon's input also happen to be the correct ASL forms required in those motion/location contexts, Simon's frequency

boosting strategy results in a VMP test performance that closely approximates that of native ASL signers.

3.6. *Analysis of handshape morphemes*

In the handshape domain, the picture appears to be quite different; Simon does not appear to be improving upon his input to the extent that he does in the motion/location categories. It is important to note, however, that with handshape, Simon's parents also perform with much lower levels of correctness. Recall that Simon's father and mother scored 46 and 45% correct on CENTRAL OBJECT handshape (see Table 1). Simon's performance on CENTRAL OBJECT handshape is 46% correct, a score which appears similar to his input and which falls outside the 95% confidence interval around the mean of his NN peer group. On SECONDARY OBJECT handshape, Simon's father and mother score 43 and 37% correct. Simon fares considerably better, scoring 59% correct and falling just inside the 95% confidence interval of his NN peers (57–77%). However, this score is considerably lower than Simon's motion/location scores, which average almost 90% correct.

What is the nature of Simon's acquisition of handshape morphemes, and why is it different from his acquisition of motion/location morphemes? A more detailed analysis of handshape morphemes will shed some light on this result. As we will show, while Simon's acquisition of handshape morphemes does not show strong frequency boosting and the general increase in consistency and systematicity noted in the acquisition of motion/location morphemes, even here Simon is in the process of organizing the morphology in ways that surpass his input. However, for handshape morphemes, some of which are acquired late even by NN learners (Kantor, 1980; T. Supalla, 1982) and which are more poorly used by Simon's parents, this process is not yet complete.

3.6.1. *Frequency boosting and handshape errors*

The lower half of Table 2 presents the individual morpheme data for the CENTRAL OBJECT handshape category. In this case, the parents' accuracy ranges from 0 to 100% correct, with an average of 47% correct. As this table shows, Simon does show frequency boosting in some cases, but not all. Over all the handshape morphemes, for both CENTRAL and SECONDARY OBJECTS, Simon shows frequency boosting for about half of the morphemes (7 out of 13 handshapes, $p > .10$ of this distribution by chance). However, a substantial number of these morphemes do not display frequency boosting (3 out of 13 match, and 3 out of 13 reduce the frequency observed in the input). In addition, as indicated by the overall scores cited above, the absolute level of frequency boosting for handshape morphemes is often much less than was observed in motion/location. Fig. 7B presents Simon's percent correct scores for the individual handshape morphemes plotted against the same scores for his mother (= triangles) and father (= squares), with the dashed diagonal line representing probability matching. In contrast to the ceiling effects Simon displayed for motion/location (see Fig. 7A), his handshape scores show a great deal of scatter.

There are several differences of potential interest between the data for handshape and those for motion/location. First, in contrast to motion/location morphemes, on handshape morphemes Simon's parents do not always use the target ASL form as their most frequent response. Instead, a variety of patterns characterize the parents' use of handshape, not all of which lead to frequency boosting. Second, the morphological system governing handshape has certain linguistic features that may make the learning process more difficult. We will illustrate these points by presenting the data for individual morphemes in greater detail.

3.6.2. *Regular use of a non-ASL form*

For motion/location morphemes, Simon's parents' most frequent form was the target ASL form. However, as suggested by the data in Table 2, this is not always the case for handshape morphemes. One different type of pattern occurs for the handshape used to mark "vehicles" (cars, boats, bicycles, trains). Here, both parents have a frequently used handshape that is not the same as that of native ASL. In native ASL, the handshape morpheme used for "vehicles" is the one illustrated in Fig. 8A. However, Simon's parents never use this handshape, and thus appear not to control it at all. Instead, with about the same frequency as their correct usage of other ASL morphemes, they produce a less marked handshape for vehicles that we call B-EDGE (Fig. 8B). B-EDGE is produced about half the time for vehicles (over both CENTRAL and SECONDARY OBJECT handshapes, father = 9/18; mother = 10/18), which is for them a reasonably consistent response. The remainder of their responses to vehicles are a variety of forms, each used with low frequency.

In this case, Simon performs frequency boosting on their usage (that is, he uses the B-EDGE handshape more frequently for vehicles than they do (B-EDGE 14/18)); but the result is not an increase in correctness relative to native ASL morphology. This example shows that when Simon's parents use a form with moderate frequency, despite its being different from ASL, Simon employs frequency boosting, just as with forms that are the same as standard ASL.

Parenthetically, the absence of the VEHICLE handshape in Simon's output is strong evidence that Simon's ASL has not been influenced by sources other than his parents. The VEHICLE handshape is acquired by native signers well before Simon's age (Kantor, 1980; Schick, 1987; T. Supalla, 1982). If Simon were exposed to this structure, he would surely have mastered it by the age of seven. Simon's use of B-EDGE in VEHICLE contexts supports our claim that Simon's linguistic output is based on input received from his late-learner parents.

3.6.3. *Highly frequent forms without meaning*

Another reason for the reduced appearance of frequency boosting among handshape morphemes is that some handshapes do not show a prominent form mapped onto meaning at all. Simon's mother very frequently uses the handshape Z-HORIZONTAL (Fig. 8C) for a variety of objects, but usually with no particular mapping onto any feature of the referent object or event that we could discern (though she also uses this handshape for long, straight, thin objects, as is appropriate in ASL). In fact, Z-HORIZONTAL is one of her most common handshape errors, for all

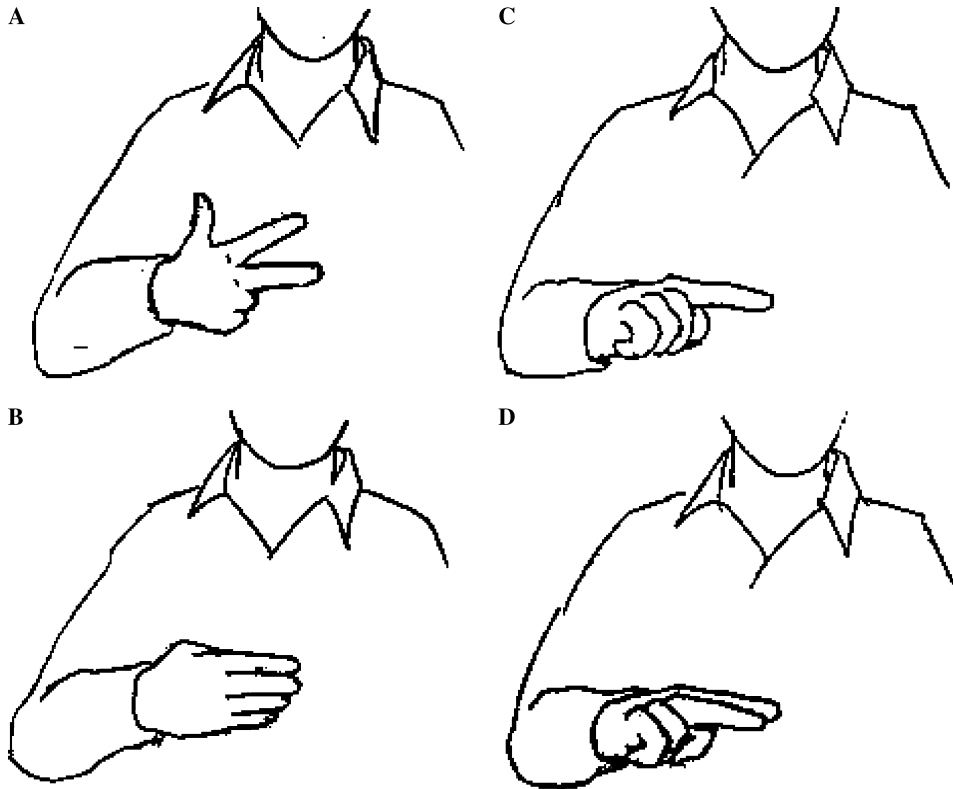


Fig. 8. (A–D) Simon's parents' handshape category errors: (A) VEHICLE classifier handshape in ASL; (B) B-EDGE less marked handshape in ASL; (C) Z-HORIZONTAL handshape in ASL; (D) H handshape in ASL.

categories of meaning. If Simon were seeking and boosting forms on the basis of sheer frequency, rather than on the basis of their consistency of mapping, we might expect him to boost the usage of this handshape.

Interestingly, Simon virtually never uses Z-HORIZONTAL for any targets except long, straight, thin objects (the set for which his mother uses the form with some consistency of meaning). This result suggests that Simon does not respond simply to absolute frequency, but rather to the consistency or correlation between form and meaning. In short, his frequency boosting is a boosting of what is most systematic or patterned in his input. In the present case, therefore, no frequency boosting occurs.

3.6.4. No form for a particular meaning

Similarly, when Simon's parents' usage does not mark semantic contrasts of ASL in a consistent way, Simon does not introduce such a contrast. Native ASL makes a morphological distinction between wide objects, narrow objects, and objects of medium width. The latter category is marked by what is called an H handshape

(Fig. 8D). Neither of Simon's parents used this H handshape, and neither had another form which they used with any consistency for this semantic category; instead they produced a variety of forms in the required contexts, each with low frequency. Interestingly, Simon also does not have any form consistently used for this category, but instead marks the referent objects with either the wide or narrow classifier, depending on their relative width.

3.6.5. *Size-and-shape specifiers and partially correct morphology*

Finally, a substantial portion of Simon's handshape usage is accounted for by another type of error, which requires a brief background to understand. Handshape morphemes in ASL verbs of motion include two somewhat different types. One type, known as semantic classifiers, indicates the semantic category of the antecedent noun (e.g., human, vehicle); each semantic classifier is one morpheme. However, a second type, known in the ASL literature as size-and-shape specifiers, or SASSes (Newport & Bellugi, 1978), has been shown by T. Supalla (1986) to have a more complex morphological structure. SASSes each consist of several morphemes, one for shape of the antecedent noun (e.g., straight vs. round), one for size (e.g., small vs. medium vs. large), and one for width or depth (e.g., thin vs. wide/deep) (T. Supalla, 1986). Within the VMP test, approximately half of the ASL handshapes tested are semantic classifiers, and the other half are SASSes (see lower portion of Table 2). For simplicity of scoring and for comparability between the two kinds of handshape morphemes, our initial scoring treated both semantic and SASS handshapes as consisting of one morpheme each, which was scored either as correct or incorrect. However, a closer analysis reveals that Simon's most serious difficulty occurs with SASSes, where his common response pattern involves getting one of the sub-morphemes correct and another incorrect. Perhaps, then, Simon's difficulty with handshape morphemes was partly due to the greater linguistic complexity of SASS morphemes. To examine this question, we rescored the CENTRAL OBJECT and SECONDARY OBJECT handshape data for all participants, but now including a scoring category for partially correct handshapes, in which an SASS response may be correct on some sub-morphemes but incorrect on others.

While Simon's father and mother's handshape scores change very little by including partially correct responses, Simon's scores increase substantially. A fairly sizeable number of Simon's handshape errors (a full 12% of his handshape responses) involve producing some of the SASS sub-morphemes correctly while omitting or replacing others. In contrast, his parents only infrequently produce some of the SASS sub-morphemes without the others (only about 5% of their handshape responses are of this type). Instead, their errors consist mainly of idiosyncratic forms, for example, fragments of frozen signs that are not part of the ASL morphological system (e.g., using the 't' handshape from the noun TOILET as the handshape of a verb referring to a toilet moving along the ground). Thus, while the parents' errors are usually inconsistent and often come from outside of the morphological system, Simon's errors suggest that he is acquiring parts of the relevant morphology.

Simon's partially correct SASS errors are similar to those of young native-signing children reported in the ASL acquisition literature (Kantor, 1980; Newport, 1981;

Newport & Meier, 1985; Schick, 1990; T. Supalla, 1982). Given the complexity of ASL morphology, young children pass through a lengthy stage in which some morphemes are correct while others are not (Newport, 1981; T. Supalla, 1982). These findings suggest that Simon may still, at age 7, be performing like much younger NN children on handshape morphology. If so, it would suggest that the lower levels of consistency of handshape usage in Simon's input, and the greater difficulty of handshape for all learners (note the difference in NN correctness for handshape vs. motion/location), may produce a more protracted learning process for Simon's acquisition of handshape.

When we consider partially as well as wholly correct HANDSHAPE morphemes, the revised scoring of handshape morphemes shows that Simon in fact substantially surpasses his input. On *revised* CENTRAL OBJECT handshape, Simon's father and mother produce 50% and 48% correct, while Simon scores 58% correct. On *revised* SECONDARY OBJECT handshape, Simon's father and mother each produce 48% correct, while Simon scores 68% correct. While this revised scoring method does not elevate Simon to the NN children's level, the character of Simon's errors suggest that, at least for SASS handshapes, he is in the process of developing morphological contrasts. His parents, on the other hand, show only meager signs of such analysis.

3.6.6. Summary

For handshape morphemes, Simon also appears to be acquiring greater structure than his parents' signing exhibits. In contrast to motion/location morphemes, however, the input for handshape morphemes is not organized in such a way that following and sharpening its most consistent tendencies necessarily results in more native-like use of ASL. Moreover, the complexity of handshape in ASL may produce only partial acquisition by Simon at age 7. Given the complexities and inconsistencies these handshape data offer the learner, then, Simon is moving the language in a more systematic and well-structured direction.

4. Discussion

In this study we have posed the following question: In the face of reduced and inconsistent linguistic input, can 7-year-old Simon surpass his input models, or does his command of American Sign Language suffer as a result of his exposure to imperfect ASL? Does he reproduce the inconsistencies of his input, or rather does he succeed in developing a more well-structured language than the one to which he was exposed? Our analyses have shown that indeed Simon surpasses his late-learner parents, and performs as well as the comparison group of eight children who received native ASL input on all but two of the seven morphological domains tested. Only on the two handshape categories does Simon's output appear to suffer as a result of his impoverished input; yet, even here, Simon appears to be in the process of surpassing his input. Simon does not incorporate the irregularities present in his parents' signing; instead, he extracts the moderately frequent forms in his input, and boosts these frequencies in his own usage. Furthermore, he appears to be developing

a morphological system with features organized in a contrastive fashion, even in a subportion of the language in which his ability to surpass his input was at first not evident.

In the present section, we focus on two questions. First, why do the acquisition of motion/location and handshape morphemes look different from one another? Second, given the patterns in our results, what are the possible mechanisms by which Simon acquires the language, and how might they relate to other phenomena of acquisition and learning?

4.1. Why is there a difference between motion/location and handshape categories?

While we have shown that Simon's ability to find consistency of structure appears to some degree in both the motion/location and the handshape categories, it is clear that there are some important differences in Simon's acquisition of these two categories. Why does the difference between motion/location and handshape arise? There are several possible reasons.

First, there is a substantial difference in Simon's parents' overall accuracy in the two domains: while they average 70–75% correct usage in motion/location (permitting Simon to surpass them by 20% points), they are only 45% accurate in handshape usage (permitting Simon to surpass them only on handshape parts, and even then only by 13% points). It is possible that, while Simon can readily attend to and acquire the regularities in a moderately inconsistent corpus, too much inconsistency can delay or degrade learning. We should note, however, that, within individual motion/location morphemes, the degree of frequency boosting was not correlated with the degree of input consistency (cf. Fig. 7A); virtually all of these morphemes were boosted to ceiling levels, regardless of their individual levels of consistency in the parents' usage. If the noisy data for handshape are preventing a similar phenomenon there, it would indicate a kind of threshold consistency required for frequency boosting to operate.

There are, however, several other possible explanations for the difference between motion/location and handshape. One alternative explanation is that, while motion/location morphemes are often iconic in form, handshape morphemes are often not; and iconicity in the mapping between form and meaning may assist Simon in this process. Counterevidence for this hypothesis comes from the fact that Simon performs worse on SASSes (which are iconic) than on semantic classifiers (which are almost totally noniconic). In addition, extensive evidence on the acquisition of ASL from native input suggests that iconicity does not ordinarily play a noticeable role (see Newport & Meier, 1985, for a review).

Another potential explanation is that classifier morphemes are difficult to acquire, either because of the complexities of their meanings or the difficulty of the morphological system. Even for children acquiring ASL from native input, control of some classifier handshapes develops much later than control over other verbs of motion morphemes (Kantor, 1980; Newport & Meier, 1985; Schick, 1987; T. Supalla, 1982, 1986), and indeed phonological control over handshape (when it is not morphologically significant) is achieved later than control over other aspects of sign phonology (Conlin, Mirus, Mauk, & Meier, 2000; Siedlicki & Bonvillian, 1993).

Classifiers are also acquired relatively late in spoken languages (Yamamoto & Keil, 1996), perhaps because of difficulties children have in understanding the semantic categories to which classifiers refer. Classifiers may also be acquired late because of the complexities of classifier morphology. Moreover, the complexities of classifiers may interact with inconsistency in the input to produce more serious acquisition problems. If any of these accounts are correct, Simon may better acquire handshape morphemes as he gets older. Further longitudinal data on Simon may show more substantial frequency boosting at a later age (though data from Ross & Newport, 1996, do not show improvement by age 9).

A final explanation is that the patterns of consistency and inconsistency differ for motion/location and handshape. For motion/location morphemes, the parents' usage centers around the correct ASL form; other usages are inconsistent and low in frequency. If Simon acquires only the moderately frequent form, his own usage will be more often correct than his parents'. In contrast, for many handshape morphemes, the parents do not have a moderately consistent form, or the one they have is not that of native ASL. Under such circumstances, Simon's tendency to boost consistent patterns will not result in improved ASL.

Whatever the correct explanation for this difference, the overall results suggest that Simon is capable of surpassing and regularizing remarkably inconsistent input data, with no degradation in his use of motion/location and only partial degradation in the more complex and more inaccurately modeled handshape morphemes. Future research may reveal whether this process requires a threshold degree of consistency, or certain patterns of consistency, to operate.

4.2. What is the nature of the learning mechanism?

The findings on Simon's handling of linguistic input suggest an important generalization: Simon appears to pay special attention to the consistency or regularity of mappings between form and meaning. When there is any moderate degree of consistency in his parents' form-meaning mappings, he learns that mapping, and increases the consistency of the mapping in his own usage. In contrast, relatively infrequent mappings are not acquired. Similarly, forms that are highly frequent, yet lack a consistent relationship to meaning (e.g., Z-HORIZONTAL handshape), are not acquired.

On first impression it may seem that Simon's successful acquisition of somewhat consistent morphemes is not terribly surprising. After all, one might argue, his linguistic input is only moderately inconsistent. What is there to do besides learn the parts that are consistent? It is important to note that there are several other outcomes that are possible, and perhaps even extremely likely, when a learning device faces data of this kind.

One possibility, given inconsistent data, is that a learner might fail. Simon's task involves acquiring the patterns among 50 or more different forms, even in just the verbs of motion. With each of these forms used incorrectly 30% of the time or more, one would expect that the learner might be slowed down or entirely stalled in trying to figure out the patterns. A second possibility, at the opposite extreme, is that a

learner might acquire all of the patterns, producing what is called ‘probability matching.’ Neither of these is the way Simon learns. Rather, he learns selectively, and then reshapes what he has acquired.

There are several acquisition phenomena that bear some resemblance to Simon’s learning of ASL morphology. These include creolization, the development of homesign, and the overregularization of morphology in the acquisition of English. While these phenomena have previously been described in ways somewhat different than our description of Simon’s acquisition of ASL, we believe that they may be related phenomena.

4.2.1. *Creolization and homesign*

Descriptions of creolization and of homesign acquisition have been framed in quite different terms than our description of Simon’s acquisition of ASL morphology. Bickerton (1984) has suggested that creolization involves the invention of grammatical devices, independent of input and dependent only on innate linguistic knowledge. On this view, while the lexical forms added to a creole grammar may come from pidgin input, the grammatical uses to which they are put are dramatically different than those in the input (see Bickerton, 1999, for discussion). Similarly, Goldin-Meadow describes the emergence of homesign as a process of invention. In contrast, the structures produced by Simon are clearly reorganizations of the input he receives, and not innovations of forms. It is possible, however, that the formation of both creoles and homesign is much like Simon’s acquisition process, involving the sharpened and grammaticized use of forms appearing inconsistently in the input.

As noted, the grammatical elements creole speakers develop come from the pidgin (or substrate language) input; however, in the creole they are used in a quite different way. Unfortunately, it has not been typical in the creolization literature to present quantitative data on the usage of forms in the pidgin as compared with the creole. Were such probabilistic data available, we might discover that the process is quite similar, perhaps, to the way in which Simon has statistically reorganized his input to create a different kind of system.

Likewise, while research on homesign has often emphasized the discontinuity between input and outcome, there is some evidence to suggest that at least part of the process by which deaf children develop a homesign system involves making sharper mappings and more systematic use of form-meaning components that may be present inconsistently in gestural input (Singleton, Morford, & Goldin-Meadow, 1993). Goldin-Meadow and Mylander (1990) show that there is considerable overlap between the deaf child’s handshape and movement repertoire and the forms that are present in the child’s input (the mother’s spontaneous gestures). What differs between input and output is not the forms used, but rather the consistency of form/meaning relationships. For example, the hearing mother may sporadically use a circular handshape when she gestures about a cup; her deaf child consistently uses the same circular handshape for all round objects. The child imposes systematicity onto the forms probabilistically present in his input. The child may use the mother’s gestures as a starting point, but then generalizes to novel combinations and to novel referential uses (Goldin-Meadow & Mylander, 1990, p. 345).

4.2.2. Conventional language acquisition

Though we have emphasized unconventional language learning in this paper, children in the process of acquiring language from rich, adequate input will also deviate from what they hear. Rather than simply mirroring their input, children typically show biases in what they learn most readily, and display a variety of phenomena which suggest that they are particularly sensitive to those aspects of input which are most regular and systematic (Slobin, 1985).

Certainly the most well-known example of this type concerns the overregularization of the English morpheme “-ed,” where young children pass through a period in which “-ed” is used to mark the past tense on both regular and irregular verbs (Berko, 1958; Ervin & Miller, 1963; Kuczaj, 1977; though see Marcus et al., 1992 and Pinker, 1999, for qualifications on how widespread this error is). Simon’s “frequency boosting” in ASL morphology is much like this overregularization of English morphology. There are, however, two interesting differences between Simon’s performance and the usual overregularization. First, Simon appears to be overregularizing virtually every morpheme in a quite complex domain. Thus, while the process may be similar, the problem of finding what is consistent must be enormously more serious when all the input morphemes are used erratically. Second, like creole speakers but not like children acquiring English, Simon appears to be permanently regularizing the language; at age 7, he does not appear to be passing through a temporary stage, after which he will retreat to a pattern more similar to his input. This is presumably because, unlike children exposed to English, Simon’s input does not contain an alternative pattern of consistency that he can later discover. For English speakers, though there is irregularity of past tense forms across verbs, there is consistency for individual lexical items; the child will eventually learn the correct irregulars, verb by verb. In contrast, Simon’s parents are genuinely inconsistent in their usage, except for the moderate consistency he has already discovered. This pattern of probabilistic consistency, surrounded by real inconsistency, would appear to be a prime circumstance for permanent language change.

Taken together, these various acquisition phenomena suggest that children are capable of organizing linguistic data in ways that surpass the input to which they are exposed. In the case of Simon, as well as in a variety of other studies of acquisition, children impose systematicity on the forms present in their input, even when the input forms are not themselves organized in this fashion. Ordinary language learners, as well as creole speakers, homesigners, and Simon achieve a more well structured linguistic system than was provided by their models.

In this study, we have shown that Simon utilizes the pieces of linguistic information provided in his input, but also that he organizes them into a system which is qualitatively different than the one to which he was exposed. Simon pays special attention to, and stores, those regularities that exist in his parents’ ASL, but he also magnifies or boosts, the consistency of the form-meaning mappings that he has extracted. Thus Simon ends up with a highly systematic grammar, while his input was “semi-linguistic” at best.

We should emphasize that, while the difference between Simon’s input and his output is in some sense merely quantitative (that is, shifts in frequency of usage),

the result is a qualitative contrast between his language and that of his parents. Simon's parents exhibit probabilistic mappings between form and meaning, with multiple forms competing somewhat unpredictably to represent the same meaning. This probabilistic type of pattern is not characteristic of morphology in any natively acquired natural language. No languages have morphemes which are used probabilistically, for example, using '-ed' to mark the past tense in an arbitrary 65% of occasions, with a scattering of other forms to mark the past tense in the other 35%.⁷ By boosting the mapping of one form onto one meaning, usually up to 90% usage or higher, Simon has changed a probabilistic set of competing forms into a rule system. In short, our data suggest that Simon is creating a type of structure that did not exist in his input. While the elements of this system were extracted from his input, their architecture is considerably different from that of his parents.

We began by suggesting that an outcome of this kind would support the claim that children acquire languages at least in part by virtue of innate constraints on the possible form of grammatical rules. We believe we have shown that Simon, like other language learners, must be operating with such constraints: rather than acquire a probabilistic set of mappings like those in his input, Simon imposes the type of regularity and orderliness of morphological rules that is characteristic of natural language systems. What kind of learning mechanism behaves in this fashion? Many kinds of devices, not necessarily restricted to language learning, will work like this: sharpening consistent mappings, and ignoring or losing inconsistent ones. At the same time, equally many kinds of devices would not produce Simon's outcome. For example, when presented with probabilistically distributed input, some types of learners will perform "probability matching," reproducing in their output the same probability distributions present in the input; other types of learners will "maximize," producing in their output only the most consistent input (see Bitterman, 1965, for the suggestion that different species learn in these distinct ways, and Hudson Kam & Newport, forthcoming, for evidence that human learners may learn in these two different ways, depending on the statistical characteristics of their input). Similarly, Simon's parents, first exposed to ASL late in life, apparently learned their language with a quite different set of constraints than Simon's. Unlike Simon, they did not succeed in forming regular patterns; instead, they acquired quite probabilistic and somewhat irregular form-meaning mappings. These contrasts suggest strongly that learning mechanisms may differ in how they respond to the kind of input Simon

⁷ While much of the literature on natural languages describes morphological (and phonological) rules as deterministic, there is an extensive literature on sociolinguistic variation, historical change, and creolization that describes rules as distributed in continua over communities, and as used in a variable or probabilistic fashion within individuals (Kroch, 1989; Labov, 1989, 1994; Rickford, 1987). However, there are several important ways in which such variable rules of natural languages are quite different from Simon's input. First, variable rules typically involve alternation between two forms, each used with relatively high frequency; in contrast, Simon's input contains multiple forms for each grammatical function, with one used a majority of the time but many others used inconsistently and with very low frequencies. Second, because the incorrect forms in Simon's input are errors, they do not have conditioning linguistic contexts. Together these characteristics may make Simon's input dramatically different for learning than any stable natural language rules, even variable rules.

received, and that an understanding of inductive learning procedures must entail a description of the internal biases various kinds of learners bring to bear. We leave to future work a specification of the precise mechanism utilized by Simon, and indeed even whether this mechanism is special to language learning or is shared by other kinds of learning. Nevertheless, we believe that Simon's performance provides important clues to understanding the nature of this learning.

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